

Appendix A – Task 1
Catalog of Early Generation Pipe and Weld Properties

Pipe background information

Nominal diameter	8-inch	203 mm
Nominal wall thickness	0.250-inch	6.4 mm
Pipe manufacturer	Bethlehem Steel Co., Yoder Mill	
Year of manufacture	1963	
Seam weld type	LF ERW, post tempered seam	
Reported pipe grade	API 5LX-46, non-expanded	

Base metal tensile test results*

Tensile strength	70,500 psi	486 MPa
Yield strength	49,700 psi	343 MPa
Elongation, %	29.0	
Reduction of area, %	42.0	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

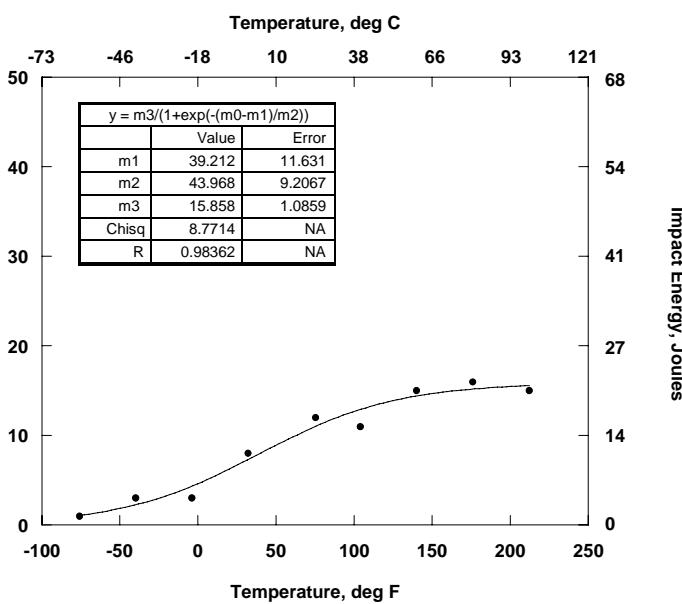
<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.253	0.310
Manganese (Mn)	0.844	1.350
Phosphorus (P)	0.007	0.040
Sulphur (S)	0.020	0.050
Silicon (Si)	0.009	
Copper (Cu)	0.051	
Tin (Sn)	0.004	
Nickel (Ni)	0.054	
Chromium (Cr)	0.040	
Molybdenum (Mo)	0.021	
Aluminum (Al)	0.003	
Vanadium (V)	0.002	
Niobium (Nb)	0.003	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0004	
Cobalt (Co)	0.007	
CE = C + (Mn/6)	0.3937	
V + Nb + Ti	0.007	

Bondline Charpy V-notch impact test results

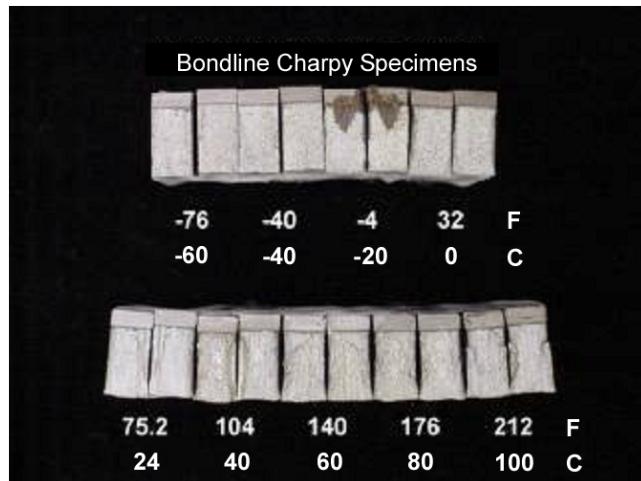
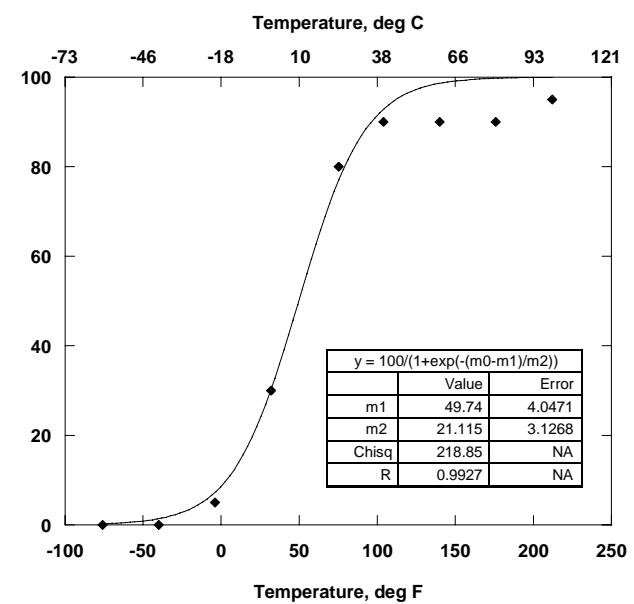
<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>			
	<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>mils</u>	<u>mm</u>	
-76	-60		1	1	0	2	0.05
-40	-40		3	4	0	2	0.05
-4	-20		3	4	5	2	0.05
32	0		8	11	30	8	0.20
75.2	24		12	16	80	14	0.36
104	40		11	15	90	15	0.38
140	60		15	20	90	18	0.46
176	80		16	22	90	19	0.48
212	100		15	20	95	22	0.56

Transition temperature, 85% shear area for specimen 100 °F 38 °C
Charpy upper shelf energy, (full size specimen) 13 ft-lbs 18 Joules

1963, LF ERW



1963, LF ERW



Ring flattening test results

N/A

General notes and observations for this pipe section:

ID connected lack of fusion (LOF) defect observed on one Charpy specimen. This pipe was used for natural gas transmission.

Pipe background information

Nominal diameter	Unknown	Plate section
Nominal wall thickness	0.250-inch	6.4 mm
Pipe manufacturer	Unknown	
Year of manufacture	1957	
Seam weld type	LF ERW	
Reported pipe grade	Assumed API 5LX-42, non-expanded	

Base metal tensile test results*

Tensile strength	65,500 psi	452 MPa
Yield strength	49,200 psi	339 MPa
Elongation, %	28.0	
Reduction of area, %	41.0	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.249	0.280
Manganese (Mn)	0.799	1.250
Phosphorus (P)	0.016	0.040
Sulphur (S)	0.028	0.050
Silicon (Si)	0.007	
Copper (Cu)	0.125	
Tin (Sn)	0.006	
Nickel (Ni)	0.022	
Chromium (Cr)	0.015	
Molybdenum (Mo)	0.005	
Aluminum (Al)	0.011	
Vanadium (V)	0.002	
Niobium (Nb)	0.003	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.033	
CE = C + (Mn/6)	0.3822	
V + Nb + Ti	0.007	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-76	-60	5	7	0	3	0.08
-40	-40	5	7	2	1	0.03
-4	-20	4	5	5	4	0.10
32	0	9	12	15	12	0.30
75.2	24	7	9	20	8	0.20
104	40	15	20	70	15	0.38
140	60	17	23	80	17	0.43
176	80	16	22	95	17	0.43
212	100	17	23	95	18	0.46

Transition temperature, 85% shear area for specimen

140 °F

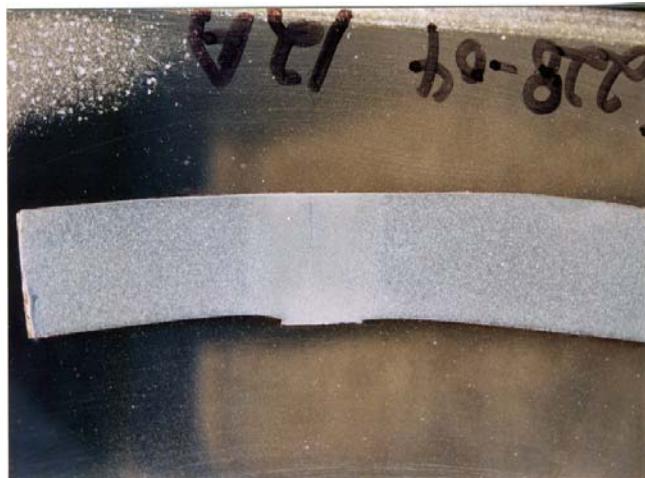
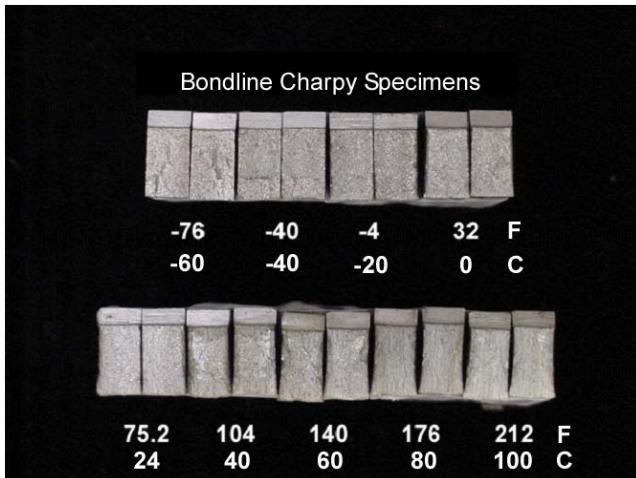
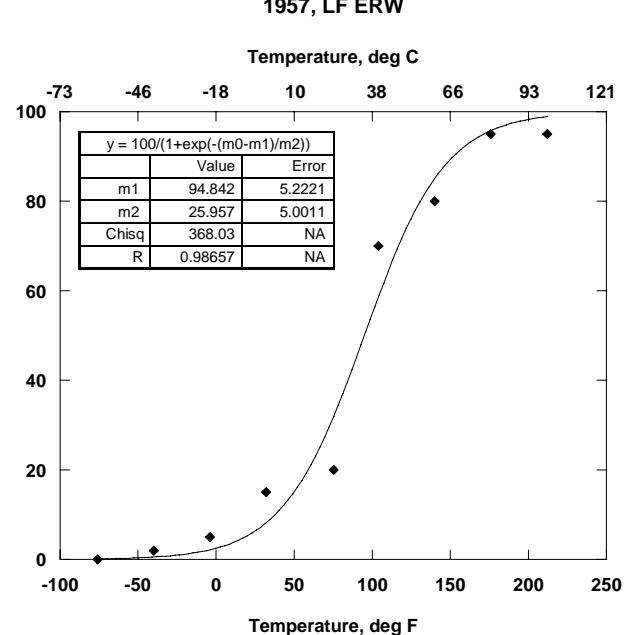
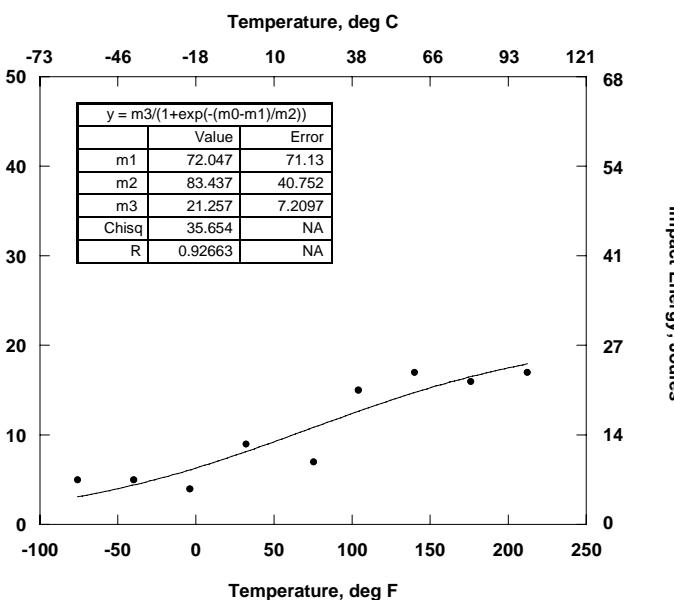
60 °C

Charpy upper shelf energy, (full size specimen)

16 ft-lbs

22 Joules

1957, LF ERW



Vickers hardness testing results

Remote from Seam			HAZ		Weld Metal or Fusion Line			
OD	Midwall	ID	Location	Hardness	other	OD	Midwall	ID
164	151	158	ID	187		231	229	210
			Midwall	190				
			OD close to fusion line	238				
			OD	203				
			ID close to fusion line	226				
			midwall close to fusion line	246				

Ring flattening test results N/A

General notes and observations for this pipe section:

Plate specimen submitted by anonymous donor. 275 psig MAOP

Pipe background information

Nominal diameter	8-inch	203 mm
Nominal wall thickness	0.233-inch	5.9 mm
Pipe manufacturer	Unknown	
Year of manufacture	1926	
Seam weld type	LF ERW	
Reported pipe grade	Unknown	

Base metal tensile test results*

Tensile strength	68,800 psi	474 MPa
Yield strength	50,300 psi	347 MPa
Elongation, %	24.4	
Reduction of area, %	45.4	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

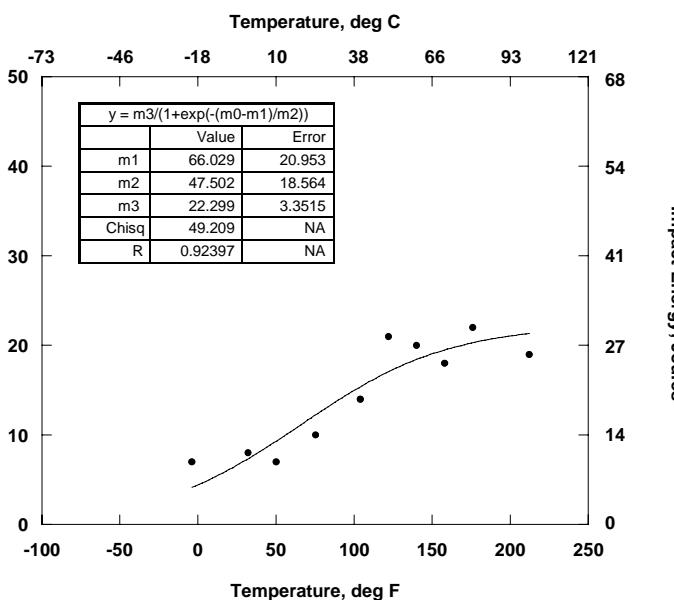
<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.243	Unknown pipe grade
Manganese (Mn)	0.698	
Phosphorus (P)	0.008	
Sulphur (S)	0.022	
Silicon (Si)	0.048	
Copper (Cu)	0.091	
Tin (Sn)	0.002	
Nickel (Ni)	0.013	
Chromium (Cr)	0.017	
Molybdenum (Mo)	0.005	
Aluminum (Al)	0.004	
Vanadium (V)	0.002	
Niobium (Nb)	0.002	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.025	
CE = C + (Mn/6)	0.3593	
V + Nb + Ti	0.006	

Bondline Charpy V-notch impact test results

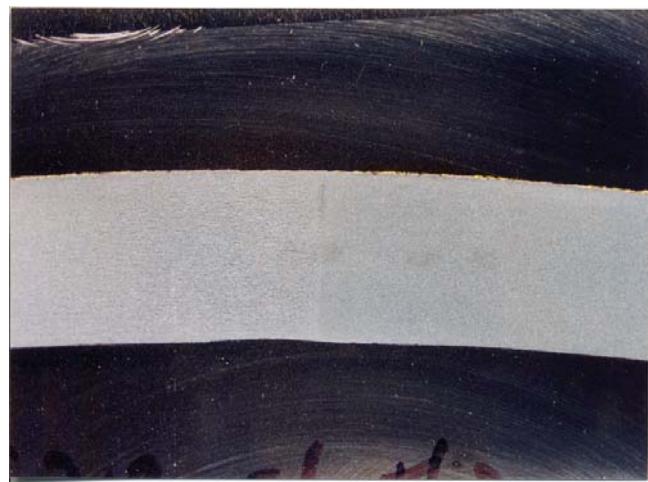
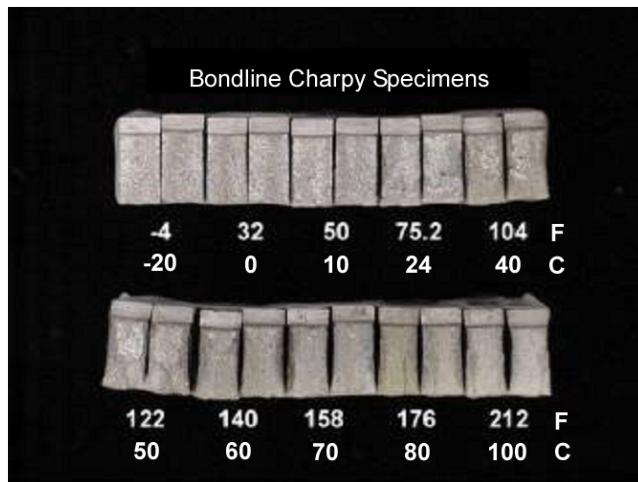
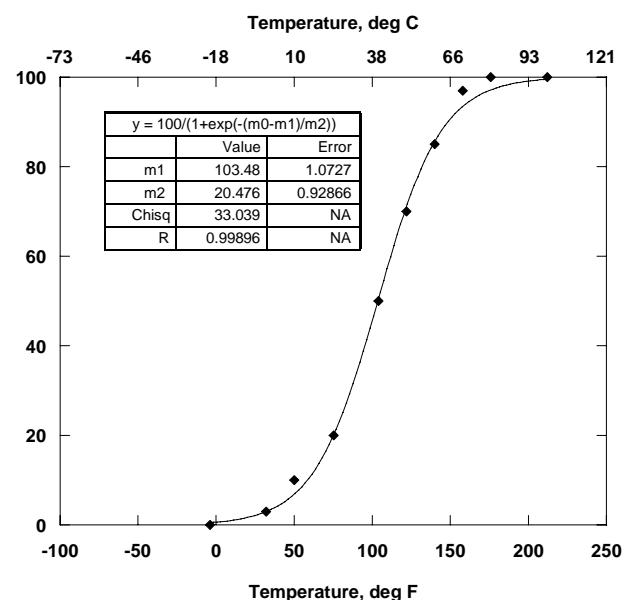
<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-4	-20	7	9	0	8	0.20
32	0	8	11	3	9	0.23
50	10	7	9	10	11	0.28
75.2	24	10	14	20	15	0.38
104	40	14	19	50	17	0.43
122	50	21	28	70	24	0.61
140	60	20	27	85	21	0.53
158	70	18	24	97	22	0.56
176	80	22	30	100	25	0.64
212	100	19	26	100	23	0.58

<u>Transition temperature, 85% shear area for specimen</u>	100	°F	38	°C
<u>Charpy upper shelf energy, (full size specimen)</u>	13	ft-lbs	18	Joules

1926, LF ERW



1926, LF ERW



Ring flattening test results

N/A

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor with ID misalignment of the seam weld

Pipe background information

Nominal diameter	18-inch	457 mm
Nominal wall thickness	0.312-inch	7.9 mm
Pipe manufacturer	Unknown	
Year of manufacture	1967	
Seam weld type	LF ERW	
Reported pipe grade	API 5LX-42, non-expanded	

Base metal tensile test results*

Tensile strength	67,300 psi	464 MPa
Yield strength	51,900 psi	358 MPa
Elongation, %	26.2	
Reduction of area, %	48.5	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.231	0.300
Manganese (Mn)	0.861	1.350
Phosphorus (P)	0.011	0.040
Sulphur (S)	0.022	0.050
Silicon (Si)	0.006	
Copper (Cu)	0.100	
Tin (Sn)	0.010	
Nickel (Ni)	0.042	
Chromium (Cr)	0.046	
Molybdenum (Mo)	0.019	
Aluminum (Al)	0.021	
Vanadium (V)	0.001	
Niobium (Nb)	0.002	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.007	
CE = C + (Mn/6)	0.3745	
V + Nb + Ti	0.005	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-40	-40	3	4	2	3	0.08
-4	-20	3	4	2	5	0.13
32	0	5	7	5	4	0.10
75.2	24	6	8	15	8	0.20
104	40	9	12	50	19	0.48
140	60	12	16	95	17	0.43
176	80	13	18	98	17	0.43
212	100	14	19	98	19	0.48
248	120	13	18	98	18	0.46

Transition temperature, 85% shear area for specimen

150 °F

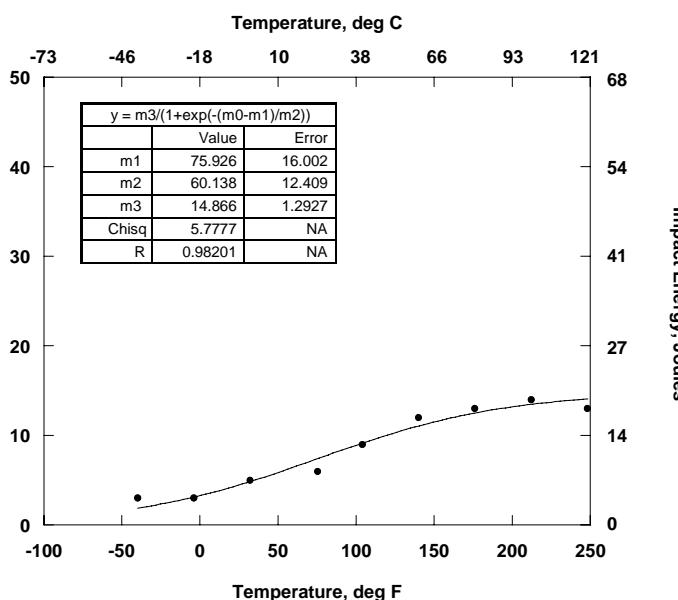
66 °C

Charpy upper shelf energy, (full size specimen)

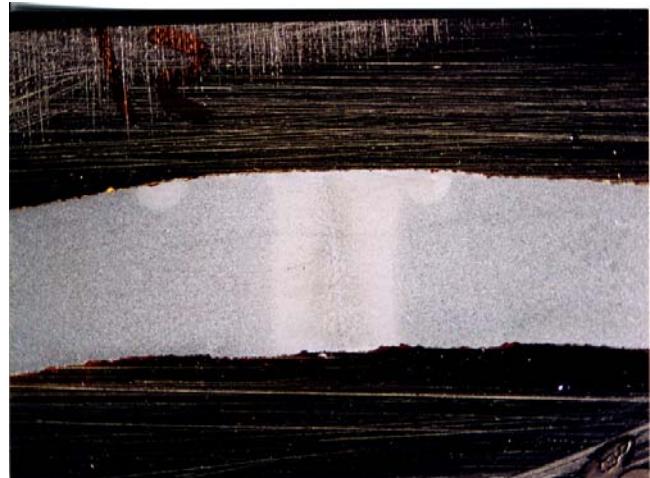
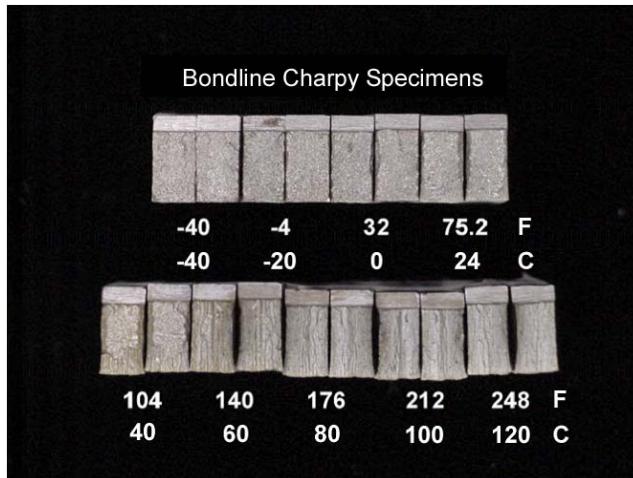
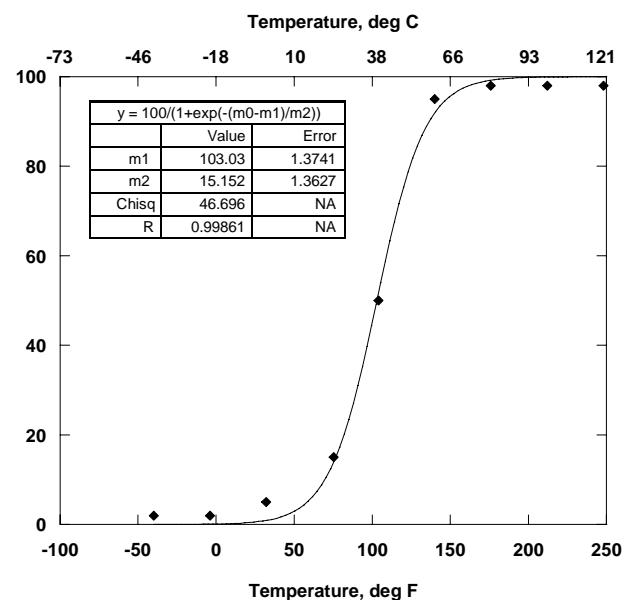
13 ft-lbs

18 Joules

1967, LF ERW



1967, LF ERW



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	Yes	Seam

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. 360 psig MAOP.

Pipe background information

Nominal diameter	34-inch	864 mm
Nominal wall thickness	0.312-inch	7.9 mm
Pipe manufacturer	A. O. Smith Corp., Houston facility	
Year of manufacture	1962	
Seam weld type	Flash Weld	
Reported pipe grade	API 5LX-42, cold-expanded	

Base metal tensile test results*

Tensile strength	55,750 psi	384 MPa
Yield strength	45,100 psi	311 MPa
Elongation, %	30.0	
Reduction of area, %	40.5	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Flash and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.252	0.280
Manganese (Mn)	1.290	1.250
Phosphorus (P)	0.019	0.040
Sulphur (S)	0.015	0.050
Silicon (Si)	0.025	
Copper (Cu)	0.016	
Tin (Sn)	0.002	
Nickel (Ni)	0.009	
Chromium (Cr)	0.032	
Molybdenum (Mo)	0.010	
Aluminum (Al)	0.003	
Vanadium (V)	0.003	
Niobium (Nb)	0.004	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.006	
CE = C + (Mn/6)	0.4670	
V + Nb + Ti	0.009	

Flash centerline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>			
	<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>mils</u>	<u>mm</u>	
-148	-100		9	12	0	8	0.20
-103	-75		9	12	0	9	0.23
-76	-60		12	16	15	13	0.33
-40	-40		19	26	45	15	0.38
-22	-30		28	38	75	32	0.81
-4	-20		21	28	80	25	0.64
32	0		29	39	95	36	0.91
75.2	24		32	43	98	37	0.94
104	40		42	57	100	46	1.17

Transition temperature, 85% shear area for specimen

15 °F

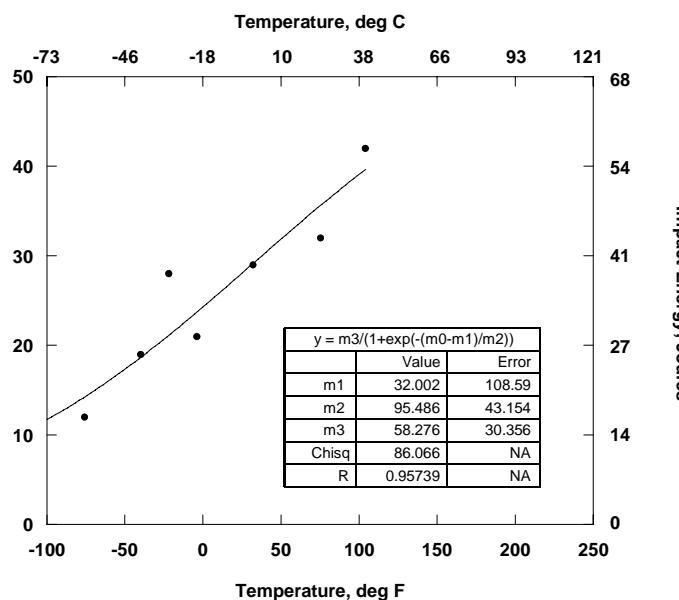
-9 °C

Charpy upper shelf energy, (full size specimen)

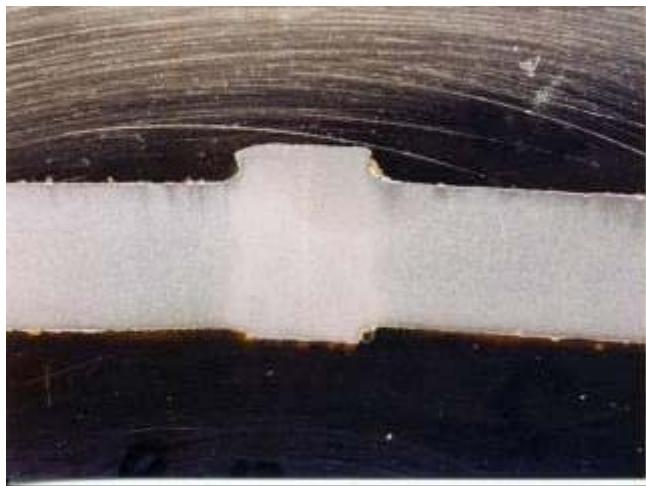
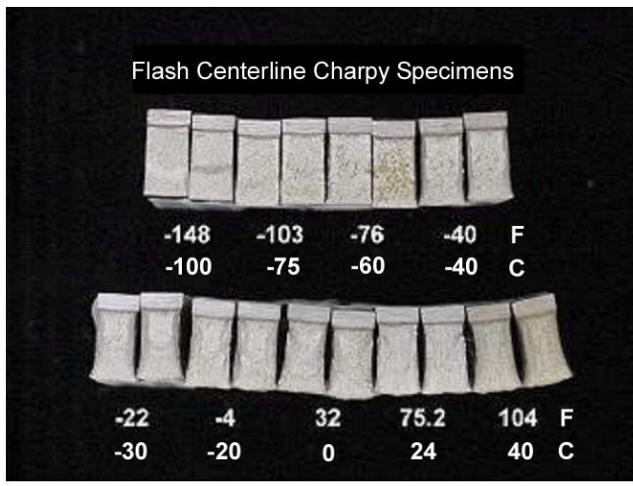
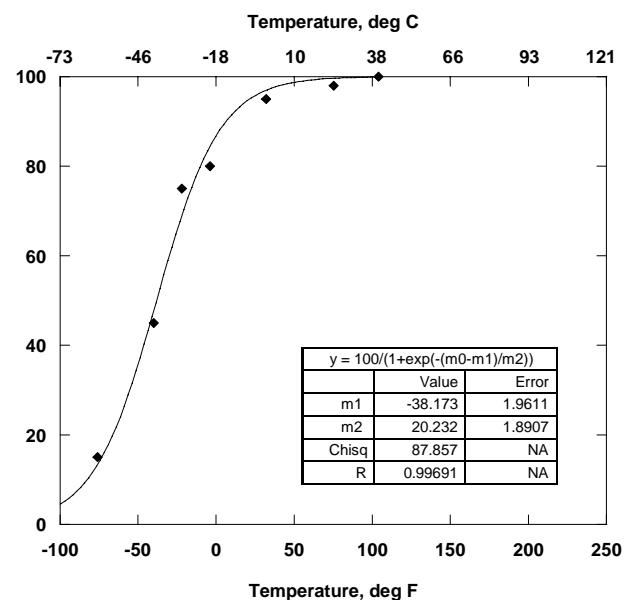
27 ft-lbs

37 Joules

1962, Flash Weld



1962, Flash Weld



Vickers hardness testing results

OD	Remote from Seam		Location	HAZ	Weld Metal or Fusion Line			
	Midwall	ID			other	OD	Midwall	ID
172	176	187	at ID corner of flash upset		202	192		approx. even with OD surface
	190		ID low temp		202			
			midwall low temp		191	195		
			OD high temp		180		202	approx. even with ID surface
			OD low temp		178			between midwall and OD
			midwall close to fusion line		199	198		

Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	Yes	Seam

General notes and observations for this pipe section:

6-inch long, ID connected Hook Crack located several inches upstream of material property testing locations. This pipe was used for crude oil transmission.

Pipe background information

Nominal diameter	20-inch	508 mm
Nominal wall thickness	0.375-inch	9.5 mm
Pipe manufacturer	Republic Steel Corp.,	Gasden, AL
Year of manufacture	1955	
Seam weld type	SSAW	
Reported pipe grade	API 5LX-56, cold-expanded	

Base metal tensile test results*

Tensile strength	77,250 psi	533 MPa
Yield strength	59,550 psi	411 MPa
Elongation, %	28.0	
Reduction of area, %	39.0	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Weld metal chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.184	0.310
Manganese (Mn)	1.100	1.350
Phosphorus (P)	0.021	0.040
Sulphur (S)	0.036	0.050
Silicon (Si)	0.262	
Copper (Cu)	0.123	
Tin (Sn)	0.013	
Nickel (Ni)	0.036	
Chromium (Cr)	0.018	
Molybdenum (Mo)	0.159	
Aluminum (Al)	0.002	
Vanadium (V)	0.004	
Niobium (Nb)	0.004	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0.0002	
Calcium (Ca)	0.0002	
Cobalt (Co)	0.024	
CE = C + (Mn/6)	0.3673	
V + Nb + Ti	0.010	

Weld metal Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>			
	<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>mils</u>	<u>mm</u>	
-76	-60		5	7	0	4	0.10
-40	-40		8	11	0	7	0.18
-4	-20		6	8	2	6	0.15
32	0		12	16	10	15	0.38
75.2	24		13	18	15	18	0.46
104	40		16	22	25	21	0.53
140	60		26	35	75	32	0.81
176	80		29	39	93	34	0.86
212	100		29	39	95	35	0.89

Transition temperature, 85% shear area for specimen

160 °F

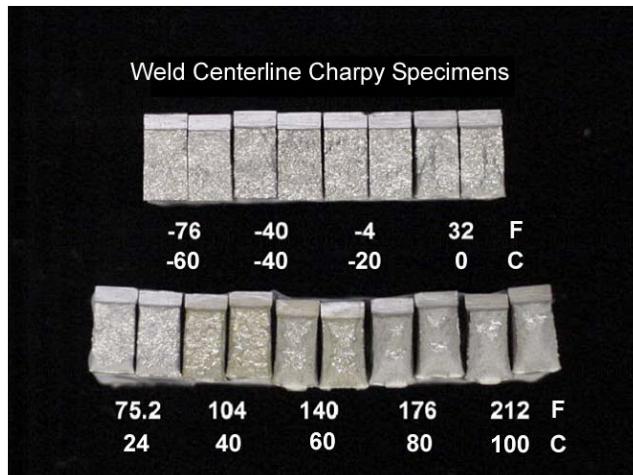
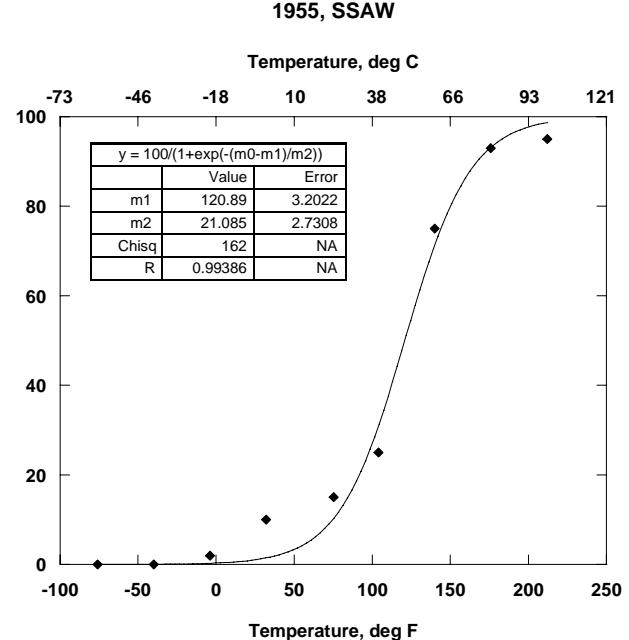
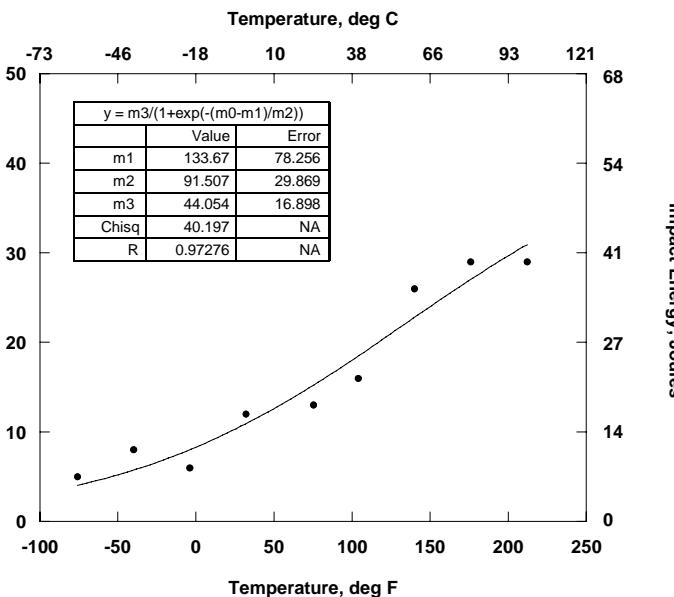
71 °C

Charpy upper shelf energy, (full size specimen)

27 ft-lbs

37 Joules

1955, SSAW



Ring flattening test results

N/A

General notes and observations for this pipe section:

It was reported that this pipe section was removed from service when transit fatigue cracks were found at the toe of the weld

Pipe background information

Nominal diameter 22-inch 559 mm
 Nominal wall thickness 0.375-inch 9.5 mm
 Pipe manufacturer National Tube Co., McKeesport, PA
 Year of manufacture 1930
 Seam weld type Lap Weld
 Reported pipe grade API 5L Gr. B, non-expanded

Base metal tensile test results*

Tensile strength	53,750 psi	371 MPa	<u>Transverse seam weld tensile test results</u>		
Yield strength	38,300 psi	264 MPa	#1	Failed in Lap @ 51,000 psi	352 MPa
Elongation, %	26.0		#2	Failed in Lap @ 47,800 psi	330 MPa
Reduction of area, %	42.5				
Mode of failure	Ductile				

*Average between two transverse tensile tests.

Lap area chemical analysis results

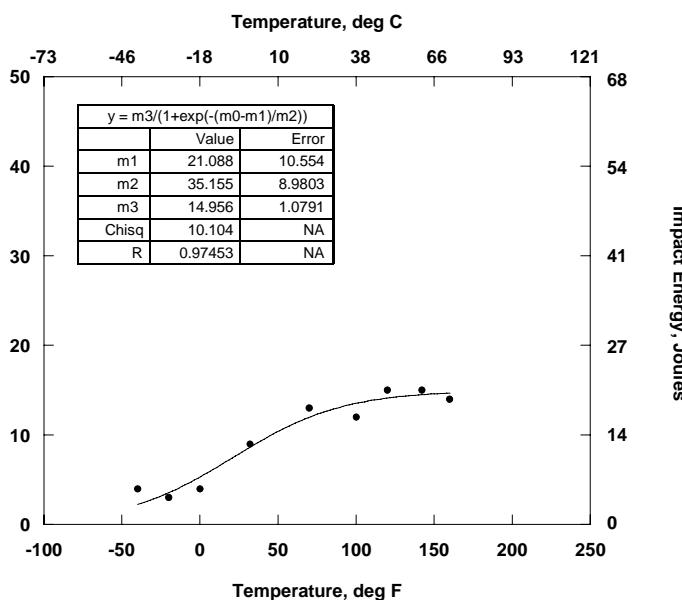
Element	Weight % of sample	Base metal max. allow (Wt %)
Carbon (C)	0.240	0.300 (for Gr. B seamless only, 1930)
Manganese (Mn)	0.750	0.300 – 0.600
Phosphorus (P)	0.014	0.045 ?
Sulphur (S)	0.022	0.060 ?
Silicon (Si)	0.040	
Copper (Cu)	0.056	
Tin (Sn)	0.004	
Nickel (Ni)	0.009	
Chromium (Cr)	0.039	
Molybdenum (Mo)	0.008	
Aluminum (Al)	0.018	
Vanadium (V)	0.002	
Niobium (Nb)	0.002	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.01	
CE = C + (Mn/6)	0.3150	
V + Nb + Ti	0.006	

Lap mid-point Charpy V-notch impact test results

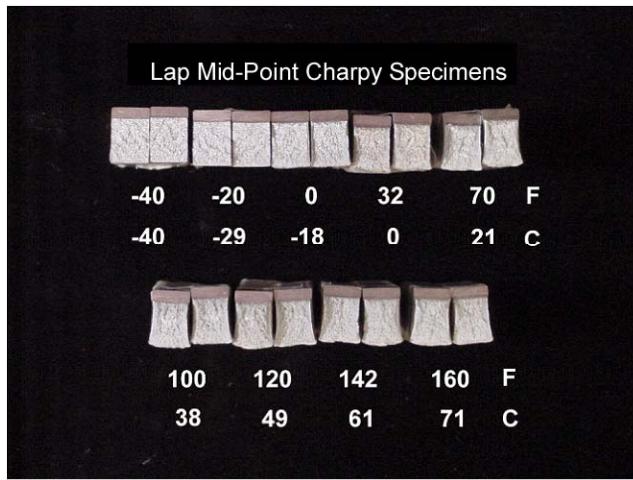
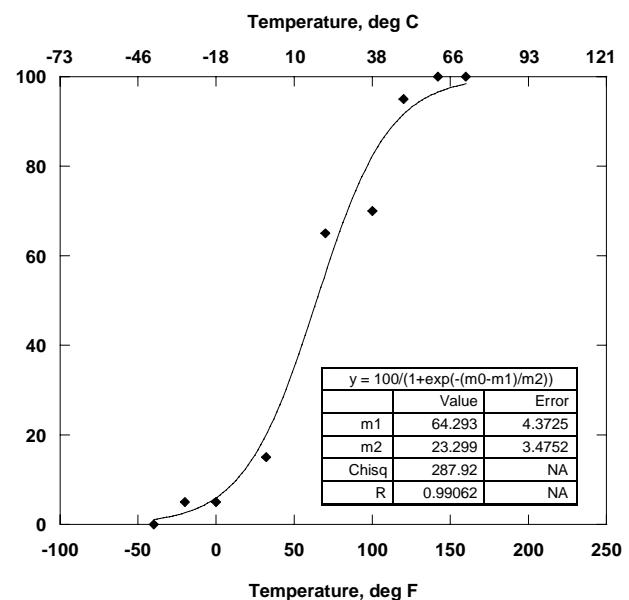
Test temperature °F	°C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion	
		ft-lbs	Joules		mils	mm
-40	-40	4	5	0	2	0.05
-20	-29	3	4	5	2	0.05
0	-18	4	5	5	4	0.10
32	0	9	12	15	6	0.15
70	21	13	18	65	13	0.33
100	38	12	16	70	14	0.36
120	49	15	20	95	17	0.43
142	61	15	20	100	18	0.46
160	71	14	19	100	17	0.43

Transition temperature, 85% shear area for specimen 118 °F 48 °C
Charpy upper shelf energy, (full size specimen) 14 ft-lbs 19 Joules

1930, Lap Weld



1930, Lap Weld



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	Yes	-
90°	No	-	Yes	Lap	-	-

General notes and observations for this pipe section:

It was reported that this pipe section was removed due to a hydrostatic test failure in the Lap Weld. Failure pressure is not known. Material property testing was conducted 3-feet downstream of the failure

Pipe background information

Nominal diameter 20-inch 508 mm
 Nominal wall thickness 0.312-inch 7.9 mm
 Pipe manufacturer A. O. Smith Corp., Houston facility?
 Year of manufacture 1959
 Seam weld type Flash Weld
 Reported pipe grade Not reported. Probably API 5LX-46

Base metal tensile test results*

Tensile strength 67,700 psi 467 MPa
 Yield strength 49,300 psi 340 MPa
 Elongation, % 24.0
 Reduction of area, % 40.5
 Mode of failure Ductile

Transverse seam weld tensile test results

#1 Failed in base metal @ 68,000 psi 469 MPa
 #2 Failed in HAZ @ 48,000 psi 331 MPa

*Average between two transverse tensile tests.

Flash and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal **max. allow (Wt %)</u>	
Carbon (C)	0.199	0.280	
Manganese (Mn)	0.990	1.250	
Phosphorus (P)	0.014	0.040	
Sulphur (S)	0.019	0.050	
Silicon (Si)	0.029	** API 5LX-46, cold expanded, 1958 API code	
Copper (Cu)	0.022		
Tin (Sn)	0.002		
Nickel (Ni)	0.017		
Chromium (Cr)	0.045		
Molybdenum (Mo)	0.008		
Aluminum (Al)	0.046		
Vanadium (V)	0.003		
Niobium (Nb)	0.003		
Zirconium (Zr)	0		
Titanium (Ti)	0.002		
Boron (B)	0		
Calcium (Ca)	0.0001		
Cobalt (Co)	0.006		
CE = C + (Mn/6)	0.3640		
V + Nb + Ti	0.008		

Flash centerline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-40	-40	1	1	0	1	0.03
-4	-20	2	3	2	2	0.05
32	0	5	7	7	8	0.20
75.2	24	5	7	15	8	0.20
122	50	11	15	50	17	0.43
140	60	13	18	95	13	0.33
176	80	9	12	95	13	0.33
212	100	13	18	98	18	0.46
248	120	10	14	100	14	0.36

Transition temperature, 85% shear area for specimen

135 °F

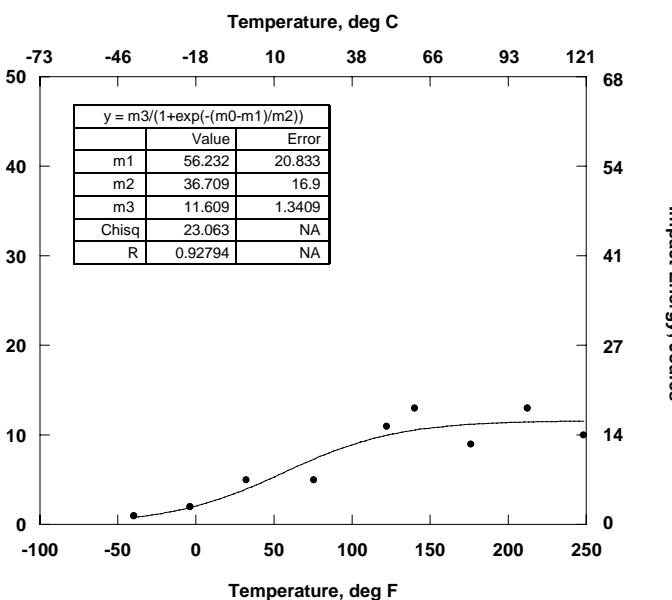
48 °C

Charpy upper shelf energy, (full size specimen)

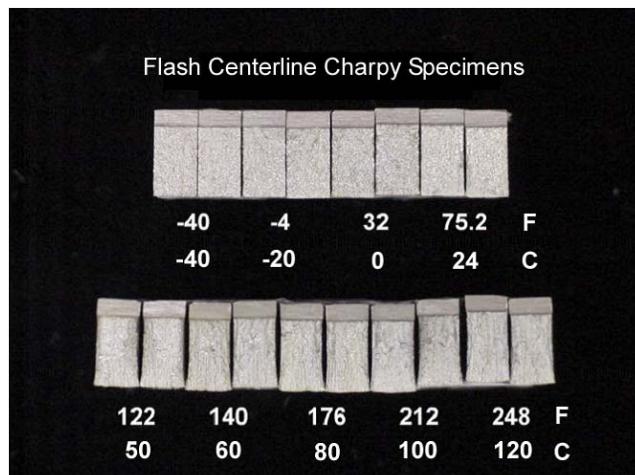
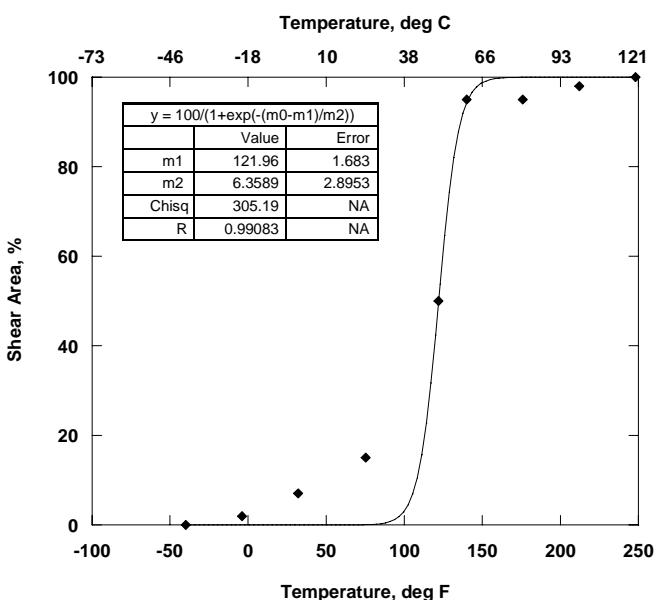
57 ft-lbs

15 Joules

1959, Flash Weld



1959, Flash Weld



HAZ Charpy V-notch impact test results

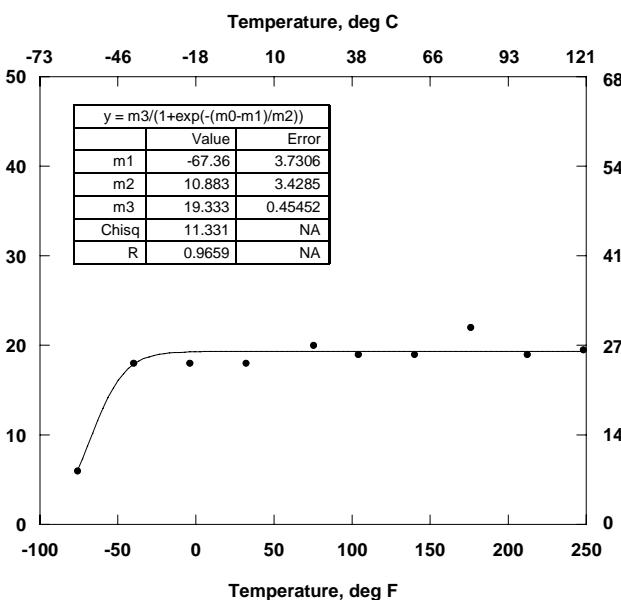
Test temperature °F	°C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
		ft-lbs	Joules		mils	mm
-76	-60	6	8	10	6	0.15
-40	-40	18	24	98	19	0.48
-4	-20	18	24	100	20	0.51
32	0	18	24	100	23	0.58
75.2	24	20	27	100	24	0.61
104	40	19	26	100	23	0.58
140	60	19	26	100	26	0.66
176	80	22	30	100	21	0.53
212	100	19	26	100	26	0.66
248	120	19.5	26	100	24	0.61

Transition temperature, 85% shear area for specimen
Charpy upper shelf energy, (full size specimen)

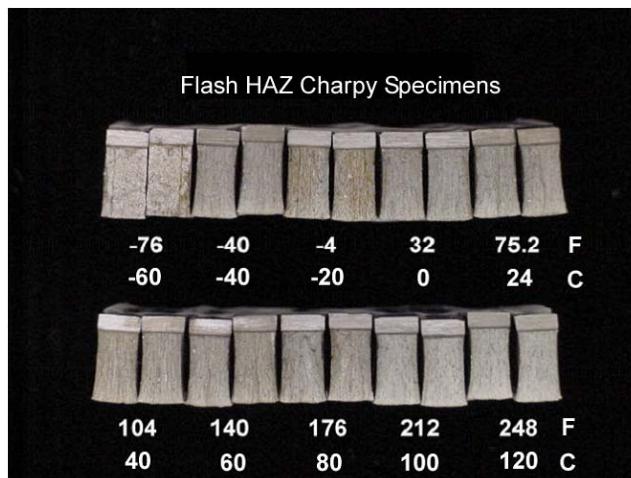
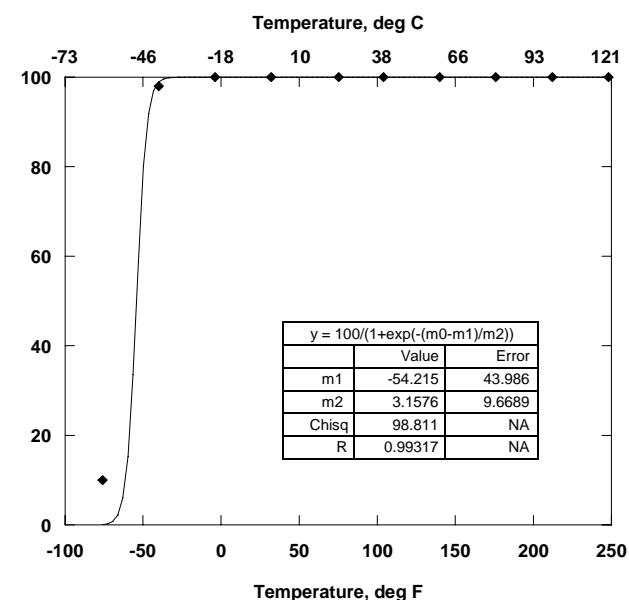
-55 °F
18 ft-lbs

-48 °C
24 Joules

1959, Flash Weld HAZ



1959, Flash Weld HAZ



Vickers hardness testing results

Remote from Seam	HAZ			Hardness	Weld Metal or Fusion Line				
	OD	Midwall	ID		other	OD	Midwall	ID	comments
194	205	197		at ID corner of flash upset	203	201	203		Cracked through fusion line at OD
	197			ID low temp	204				
				ID low temp	191				
				midwall low temp	207				
				OD high temp	226				
				OD low temp	187				
				midwall close to fusion line	226				
				ID high temp	219				
				1/3T from OD near fusion line	213				
				OD high temp, HAZ side of crack	205				

Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	Yes	HAZ

General notes and observations for this pipe section:

This pipe section reportedly had MnS inclusions at the bondline. There was also a 7-inch long, ID connected hook crack downstream from the area of material property testing. This pipe was used for natural gas transmission.

Pipe background information

Nominal diameter 26-inch 660 mm
 Nominal wall thickness 0.281-inch 7.1 mm
 Pipe manufacturer A. O. Smith Corp.
 Year of manufacture 1957
 Seam weld type Flash Weld
 Reported pipe grade Not reported. Probably API 5LX-42

Base metal tensile test results*

Tensile strength 62,200 psi 429 MPa
 Yield strength 44,000 psi 303 MPa
 Elongation, % 30.0
 Reduction of area, % 39.5
 Mode of failure Ductile

*Average between two transverse tensile tests.

Transverse seam weld tensile test results

#1	<u>Failed in base metal</u> @ 64,000 psi	441 MPa
#2	<u>Failed in base metal</u> @ 61,900 psi	427 MPa

Flash and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal **max. allow (Wt %)</u>	
Carbon (C)	0.202	0.280	
Manganese (Mn)	0.900	1.250	
Phosphorus (P)	0.014	0.040	
Sulphur (S)	0.019	0.050	
Silicon (Si)	0.054	** API 5LX-42, cold expanded, 1957 API code	
Copper (Cu)	0.062		
Tin (Sn)	0.009		
Nickel (Ni)	0.017		
Chromium (Cr)	0.029		
Molybdenum (Mo)	0.008		
Aluminum (Al)	0.03		
Vanadium (V)	0.003		
Niobium (Nb)	0.003		
Zirconium (Zr)	0		
Titanium (Ti)	0.002		
Boron (B)	0		
Calcium (Ca)	0.0001		
Cobalt (Co)	0.006		
CE = C + (Mn/6)	0.3520		
V + Nb + Ti	0.008		

Flash centerline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-25	-32	1	1	0	2	0.05
0	-18	2	3	3	2	0.05
25	-4	5	7	7	5	0.13
50	10	8	11	15	5	0.13
75	24	11	15	55	13	0.33
100	38	11	15	70	12	0.30
125	52	13	18	75	17	0.43
150	66	13	18	98	18	0.46
185	85	14	19	100	21	0.53

Transition temperature, 85% shear area for specimen

130 °F

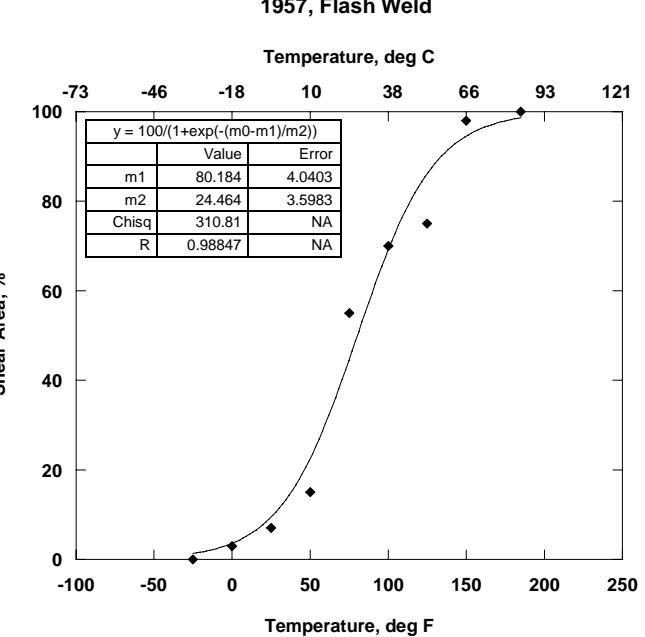
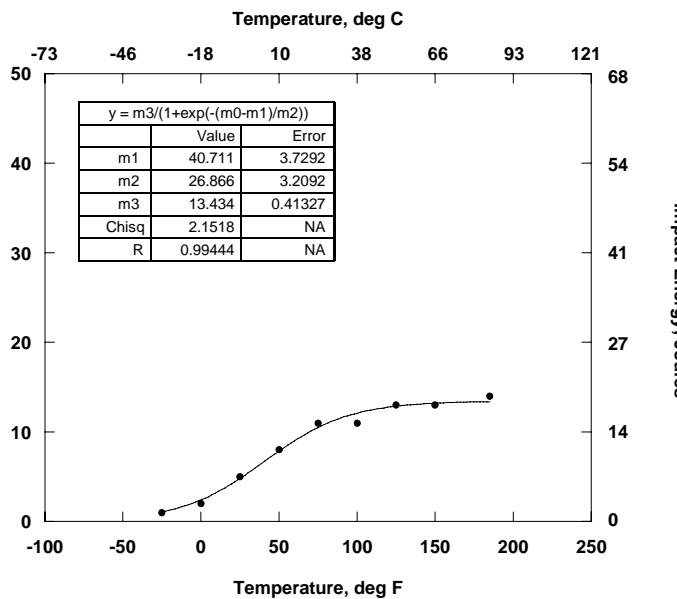
54 °C

Charpy upper shelf energy, (full size specimen)

13 ft-lbs

18 Joules

1957, Flash Weld



Charpy specimens were not returned for photo documentation

HAZ Charpy V-notch impact test results

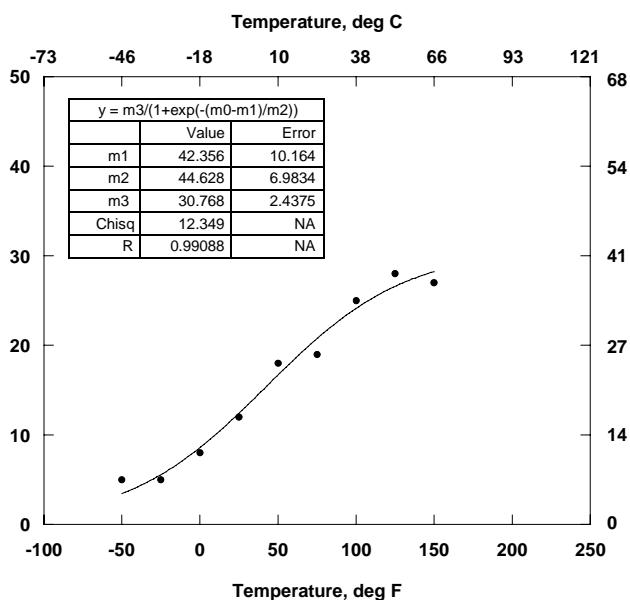
Test temperature °F	°C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils	
		ft-lbs	Joules		mils	mm
-50	-46	5	7	0	5	0.13
-25	-32	5	7	5	4	0.10
0	-18	8	11	20	10	0.25
25	-4	12	16	30	11	0.28
50	10	18	24	75	18	0.46
75	24	19	26	85	23	0.58
100	38	25	34	95	29	0.74
125	52	28	38	100	30	0.76
150	66	27	37	100	32	0.81

Transition temperature, 85% shear area for specimen
Charpy upper shelf energy, (full size specimen)

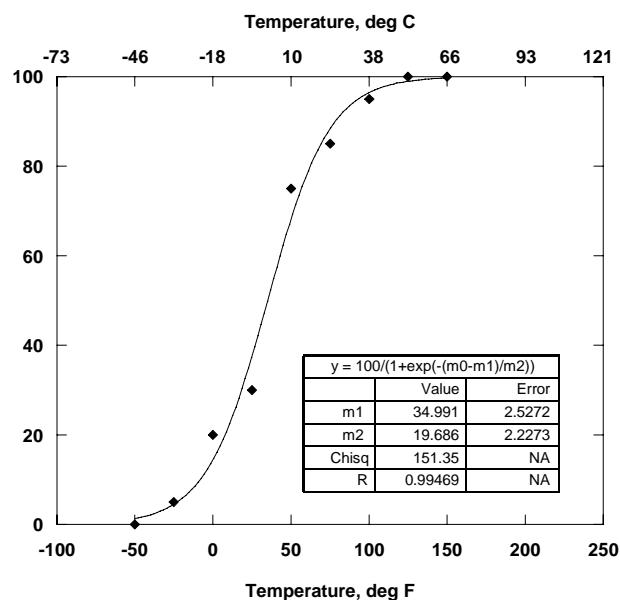
75 °F
19 ft-lbs

24 °C
26 Joules

1957, Flash Weld HAZ



1957, Flash Weld HAZ



Charpy specimens were not returned for photo documentation

Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-

General notes and observations for this pipe section:

No defects were associated with this pipe section. Conflicting information was reported about which mill manufactured this pipe, therefore it may have come from Milwaukee or Houston.

Pipe background information

Nominal diameter	16-inch	406 mm
Nominal wall thickness	0.250-inch	6.4 mm
Pipe manufacturer	Lone Star	
Year of manufacture	1955	
Seam weld type	LF ERW	
Reported pipe grade	API 5LX-42, non-expanded	

Base metal tensile test results*

Tensile strength	66,100 psi	456 MPa
Yield strength	46,200 psi	319 MPa
Elongation, %	31.0	
Reduction of area, %	42.0	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

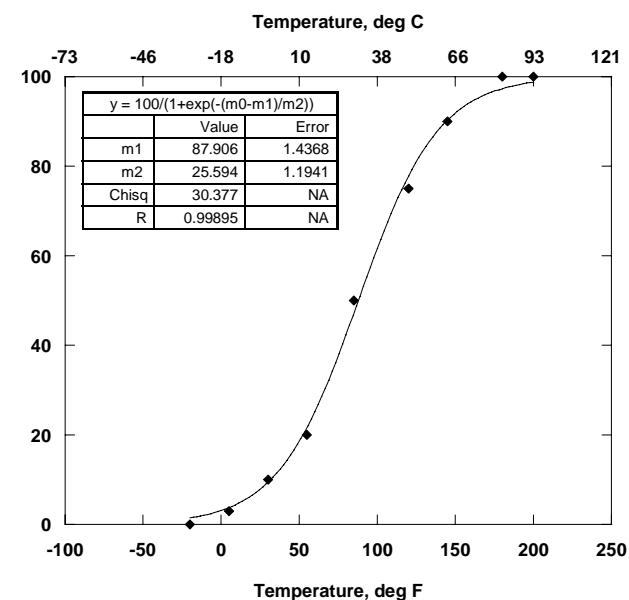
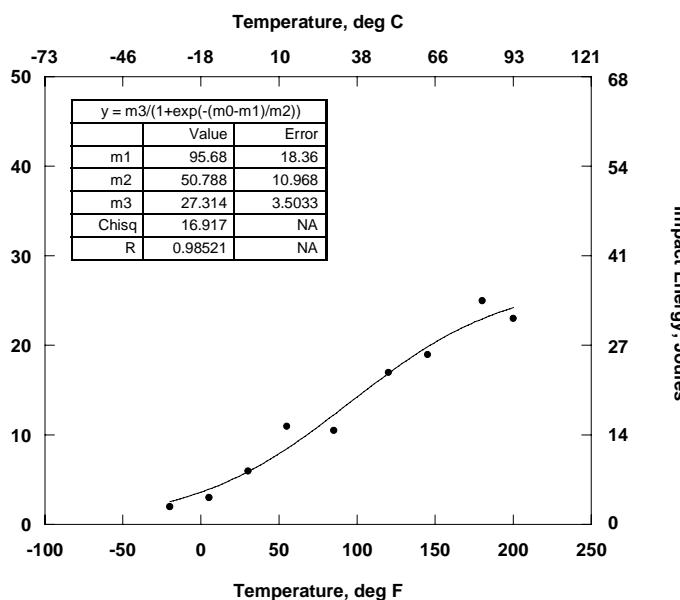
<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.212	0.300
Manganese (Mn)	1.103	1.350
Phosphorus (P)	0.008	0.040
Sulphur (S)	0.020	0.050
Silicon (Si)	0.107	
Copper (Cu)	0.060	
Tin (Sn)	0.009	
Nickel (Ni)	0.030	
Chromium (Cr)	0.021	
Molybdenum (Mo)	0.008	
Aluminum (Al)	0.03	
Vanadium (V)	0.001	
Niobium (Nb)	0.003	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0002	
Cobalt (Co)	0.005	
CE = C + (Mn/6)	0.3958	
V + Nb + Ti	0.006	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>Percent</u>	<u>mils</u>	<u>mm</u>
-20	-29	2	3	0	5	0.13
5	-15	3	4	3	8	0.20
30	-1	6	8	10	12	0.30
55	13	11	15	20	13	0.33
85	29	10.5	14	50	16	0.41
120	49	17	23	75	19	0.48
145	63	19	26	90	20	0.51
180	82	25	34	100	23	0.58
200	93	23	31	100	21	0.53

Transition temperature, 85% shear area for specimen 130 °F 54 °C
Charpy upper shelf energy, (full size specimen) 18 ft-lbs 24 Joules

1955, LF ERW



Photographs of Charpy specimens were not found in this record



Ring flattening test results N/A

Remote from Seam			HAZ		Weld Metal or Fusion Line			
OD	Midwall	ID	Location	Hardness	other	OD	Midwall	ID
168	157	167	ID near fusion line	191				
	161		midwall near fusion line	209				
			OD near fusion line	227				
			ID low temp	179				
			1/3T from OD low temp	194				
			midwall low temp	185				
			1/3T from OD lower temp	193				
			OD low temp	220				

General notes and observations for this pipe section:

This pipe section was reported to have stitching in the ERW seam, downstream from the area of material property testing.

Pipe background information

Nominal diameter	16-inch	406 mm
Nominal wall thickness	0.266-inch	6.8 mm
Pipe manufacturer	Unknown.	Possibly Republic Steel
Year of manufacture	1930	
Seam weld type	LF ERW	
Reported pipe grade	Not reported. Probably API 5L Gr. B, non-expanded	

Base metal tensile test results*

Tensile strength	65,800 psi	454 MPa
Yield strength	44,600 psi	308 MPa
Elongation, %	30.2	
Reduction of area, %	54.4	
Mode of failure	Ductile	

Transverse seam weld tensile test results

#1	Failed in base metal @ 64,900 psi	447 MPa
#2	Failed in base metal @ 66,900 psi	461 MPa

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

Element	Weight % of sample	Base metal max. allow (Wt %)
Carbon (C)	0.235	0.300 (for Gr. B seamless only, 1930)
Manganese (Mn)	0.490	0.300 – 0.600
Phosphorus (P)	0.008	0.045 ?
Sulphur (S)	0.018	0.060 ?
Silicon (Si)	0.007	
Copper (Cu)	0.051	
Tin (Sn)	0.006	
Nickel (Ni)	0.060	
Chromium (Cr)	0.054	
Molybdenum (Mo)	0.010	
Aluminum (Al)	0.002	
Vanadium (V)	0.001	
Niobium (Nb)	0.002	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0	
Cobalt (Co)	0.006	
CE = C + (Mn/6)	0.3167	
V + Nb + Ti	0.005	

Flash centerline Charpy V-notch impact test results

Test temperature °F	°C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
		ft-lbs	Joules		mils	mm
-75	-59	2	3	0	0	0
-60	-51	4	5	0	6	0.15
-40	-40	10	14	0	8	0.20
-20	-29	10	14	0	6	0.15
-10	-23	14	19	8	15	0.38
0	-18	30	41	60	26	0.66
24	-4	38	52	100	34	0.86
40	4	40	54	100	30	0.76

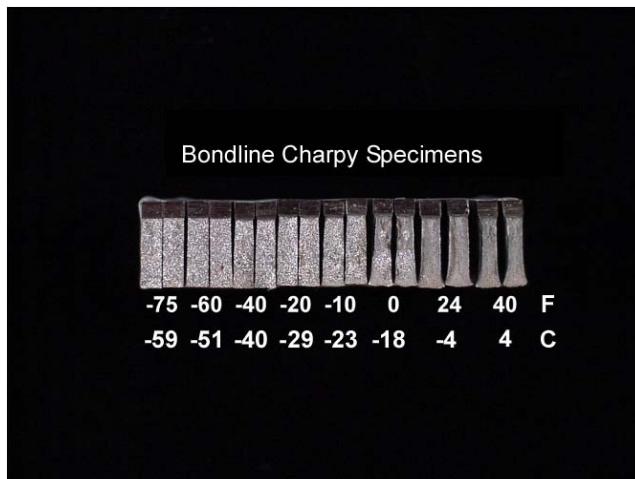
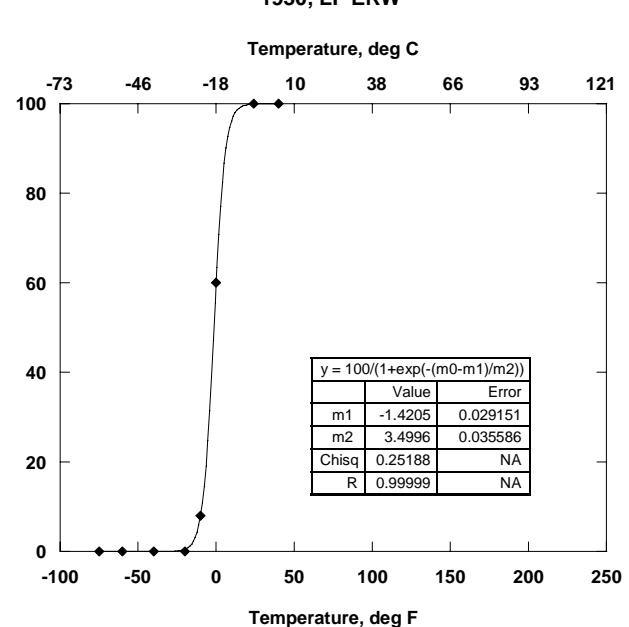
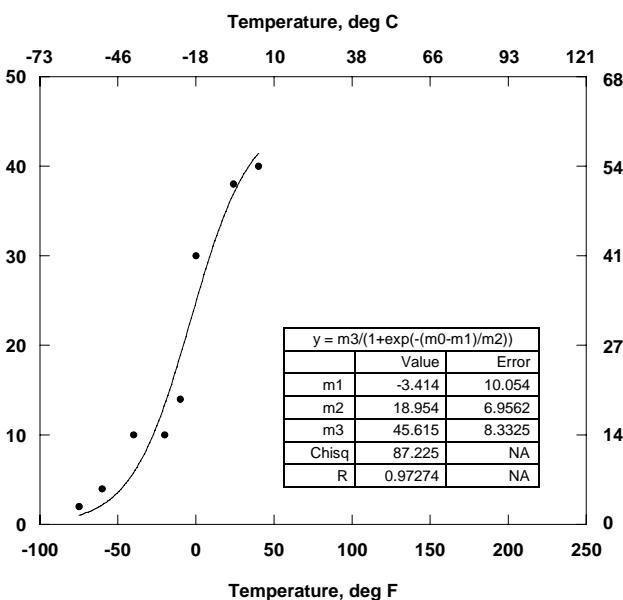
Transition temperature, 85% shear area for specimen

20 °F -7 °C

Charpy upper shelf energy, (full size specimen)

37 ft-lbs 50 Joules

1930, LF ERW



HAZ Charpy V-notch impact test results

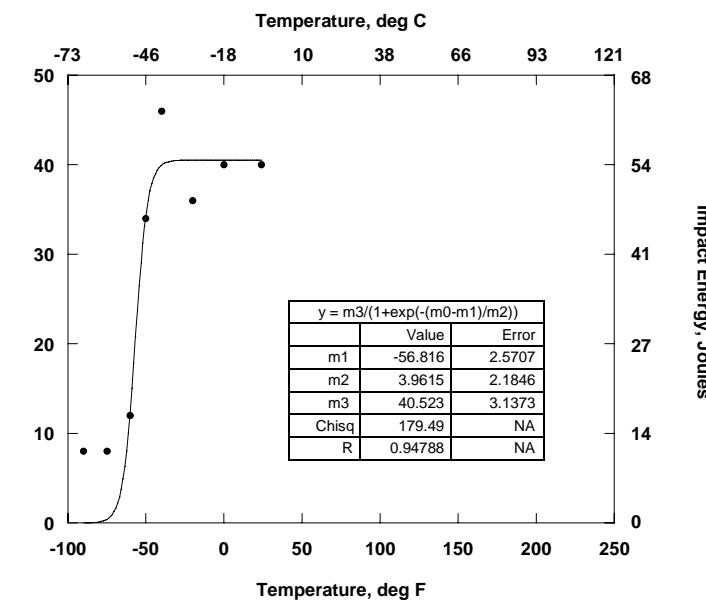
Test temperature °F	°C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
		ft-lbs	Joules		mils	mm
-90	-68	8	11	0	8	0.20
-75	-59	8	11	0	7	0.18
-60	-51	12	16	8	12	0.30
-50	-46	34	46	70	33	0.84
-40	-40	46	62	85	31	0.79
-20	-29	36	49	98	34	0.86
0	-18	40	54	100	33	0.84
24	-4	40	54	100	36	0.91

Transition temperature, 85% shear area for specimen
Charpy upper shelf energy, (full size specimen)

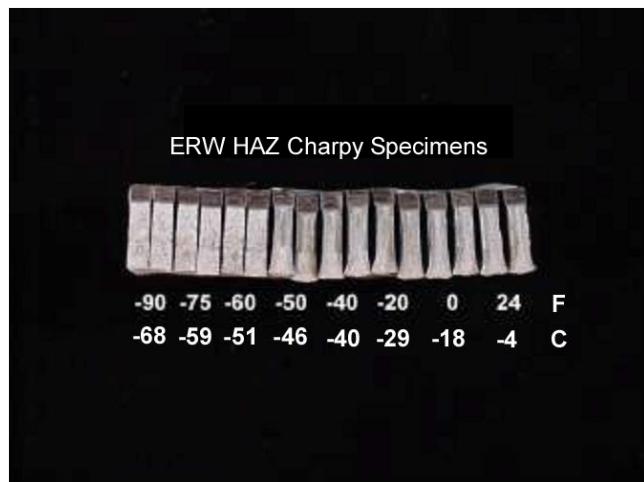
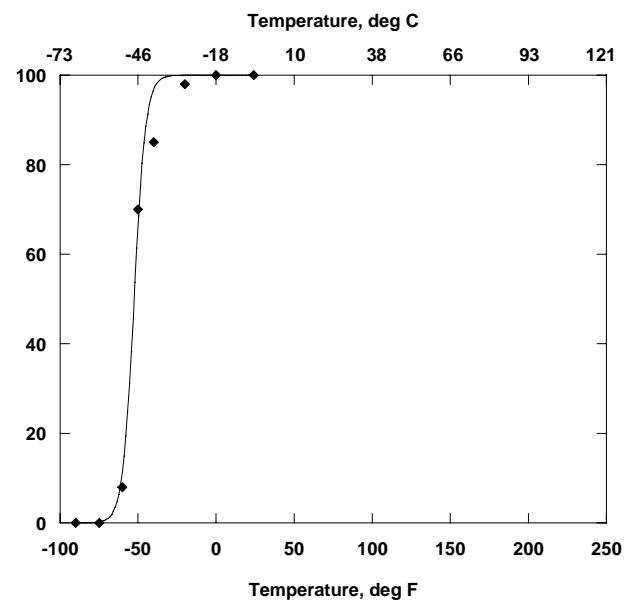
-40 °F
46 ft-lbs

-40 °C
62 Joules

1930, LF ERW HAZ



1930, LF ERW HAZ



Vickers hardness testing results

Remote from Seam			Location	HAZ	Weld Metal or Fusion Line				comments
OD	Midwall	ID			other	OD	Midwall	ID	
164	161	161	OD low temp		173	181	175	164	
			OD low temp		164	177			between OD and midwall
			midwall low temp		164				
			ID low temp		167				
			ID low temp		151				
			OD near fusion line		180				
			High CE banding		191				
			midwall near fusion line		176				

Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-



General notes and observations for this pipe
section:

Pipe section submitted by anonymous donor.
Offset skelp edges at the seam and
inadequate trim of the upset at the ID

Pipe background information

Nominal diameter 8-inch 203 mm
 Nominal wall thickness 0.188-inch 4.8 mm
 Pipe manufacturer Cal-metal Pipe Corporation
 Year of manufacture 1963
 Seam weld type HFC ERW
 Reported pipe grade API 5LX-46, non-expanded

Base metal tensile test results*

Tensile strength 62,200 psi 429 MPa
 Yield strength 53,200 psi 367 MPa
 Elongation, % 26.0
 Reduction of area, % 45.0
 Mode of failure Ductile

Transverse seam weld tensile test results

#1 Failed in base metal @ 71,000 psi 490 MPa
 #2 Failed in base metal @ 64,300 psi 443 MPa

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.213	0.300
Manganese (Mn)	0.695	1.350
Phosphorus (P)	0.009	0.040
Sulphur (S)	0.016	0.050
Silicon (Si)	0.012	
Copper (Cu)	0.125	
Tin (Sn)	0.020	
Nickel (Ni)	0.039	
Chromium (Cr)	0.024	
Molybdenum (Mo)	0.007	
Aluminum (Al)	0	
Vanadium (V)	0.001	
Niobium (Nb)	0.002	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0	
Cobalt (Co)	0.018	
CE = C + (Mn/6)	0.3288	
V + Nb + Ti	0.005	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-75	-59	8	11	0	9	0.23
-60	-51	8	11	0	7	0.18
-40	-40	10	14	20	13	0.33
-20	-29	8	11	20	16	0.41
0	-18	23	31	95	26	0.66
10	-12	18	24	100	24	0.61
22	-6	18	24	100	24	0.61
40	4	18	24	100	27	0.69
60	16	17	23	100	25	0.64
80	27	22	30	100	29	0.74

Transition temperature, 85% shear area for specimen

-5 °F

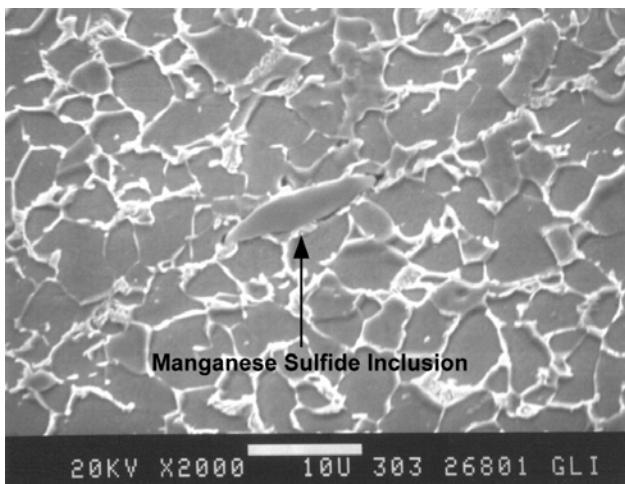
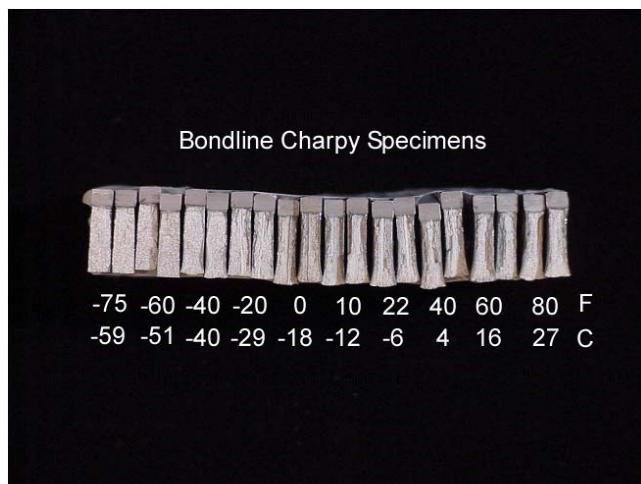
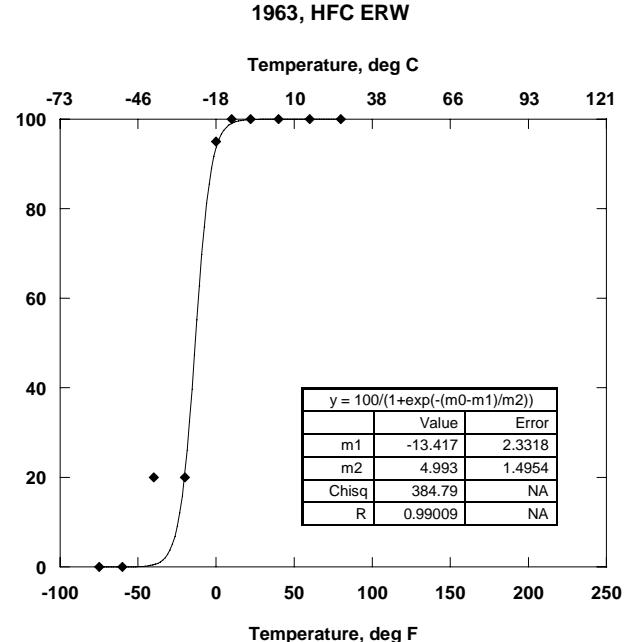
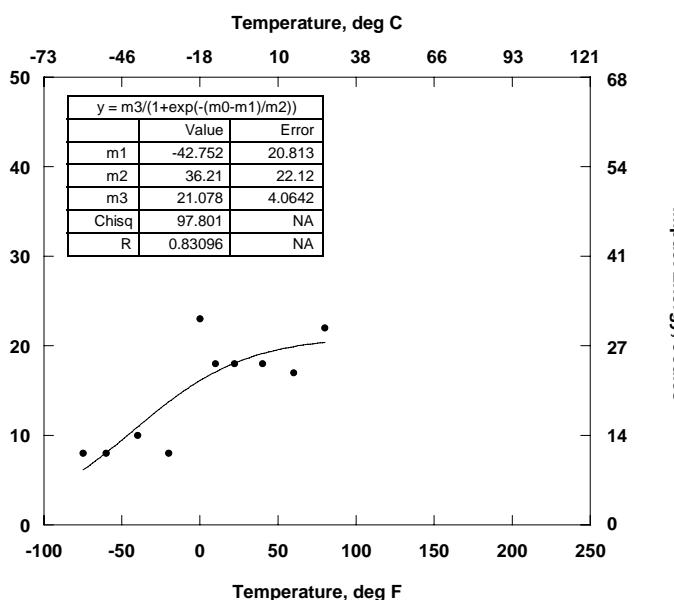
-21 °C

Charpy upper shelf energy, (full size specimen)

20 ft-lbs

27 Joules

1963, HFC ERW



Ring flattening test results N/A

General notes and observations for this pipe section:

This pipe section was removed after rupturing during a hydrostatic test. The rupture occurred because of a 7-inch long hook crack in the seam weld. MnS inclusions were found in the HAZ near the hook crack. The rupture occurred at 1,655 psig. Material property testing was conducted several inches away from the rupture. This pipe was used for natural gas transmission.

Pipe background information

Nominal diameter 8-inch 203 mm
 Nominal wall thickness 0.322-inch 8.2 mm
 Pipe manufacturer Unknown
 Year of manufacture 1932
 Seam weld type Lap Weld
 Reported pipe grade Probably API 5L Gr. B, non-expanded

Base metal tensile test results*

Tensile strength 49,400 psi 341 MPa
 Yield strength 35,600 psi 245 MPa
 Elongation, % 24.0
 Reduction of area, % 39.5
 Mode of failure Ductile

Transverse seam weld tensile test results

#1 Failed in base metal @ 41,000 psi 214 MPa
 #2 Failed in base metal @ 47,900 psi 261 MPa

*Average between two transverse tensile tests.

Lap area chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.193	0.300 (for Gr. B seamless only, 1930)
Manganese (Mn)	0.550	0.300 – 0.600
Phosphorus (P)	0.032	0.045 ?
Sulphur (S)	0.019	0.060 ?
Silicon (Si)	0.031	
Copper (Cu)	0.049	
Tin (Sn)	0.004	
Nickel (Ni)	0.007	
Chromium (Cr)	0.037	
Molybdenum (Mo)	0.010	
Aluminum (Al)	0.028	
Vanadium (V)	0.002	
Niobium (Nb)	0.008	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.01	
CE = C + (Mn/6)	0.2847	
V + Nb + Ti	0.010	

Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	Yes	Lap	-	-
90°	No	-	Yes	Lap	-	-

General notes and observations for this pipe section:

It was reported that this pipe section had entrapped oxide layers in the Lap Weld, downstream from the area of material property testing. Tensile tests across the seam both failed in the Lap. Insufficient material remained for Charpy impact tests.

Pipe background information

Nominal diameter	16-inch	406 mm
Nominal wall thickness	0.312-inch	7.9 mm
Pipe manufacturer	US Steel, bought by Camp Hill Corp.	
Year of manufacture	Unknown	
Seam weld type	HFC ERW, Thermatool	
Reported pipe grade	API 5LX-52, possibly cold-expanded	

Base metal tensile test results*

Tensile strength	72,900 psi	503 MPa
Yield strength	56,100 psi	387 MPa
Elongation, %	31.6	
Reduction of area, %	46.4	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.262	Unknown year of manufacture
Manganese (Mn)	1.250	Applicable code not known
Phosphorus (P)	0.012	
Sulphur (S)	0.020	
Silicon (Si)	0.037	
Copper (Cu)	0.013	
Tin (Sn)	0.004	
Nickel (Ni)	0.010	
Chromium (Cr)	0.030	
Molybdenum (Mo)	0.009	
Aluminum (Al)	0.004	
Vanadium (V)	0.002	
Niobium (Nb)	0.002	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.005	
CE = C + (Mn/6)	0.4703	
V + Nb + Ti	0.006	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>			
	<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>Percent</u>	<u>mils</u>	<u>mm</u>
45	7		13	18	32	16	0.23
45	7		12	16	35	12	0.18
45	7		10.5	14	29	15	0.33
45	7		12	16	30	14	0.41
45	7		10	14	40	16	0.66
45	7		14.5	20	35	19	0.61
45	7		10.5	14	40	12	0.61
45	7		13.5	18	45	13	0.69
<u>Average value</u>			12	16	36	15	0.46

Bondline Charpy V-notch impact test results

Test temperature °F	Test temperature °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion	
		ft-lbs	Joules		mils	mm
65	18	13.5	18	54	17	0.43
65	18	14	19	52	20	0.51
65	18	14.5	20	50	19	0.48
65	18	10.5	14	45	15	0.38
65	18	13	18	40	17	0.43
65	18	12.5	17	40	17	0.43
65	18	13	18	45	15	0.38
65	18	14.5	20	54	16	0.41
<u>Average value</u>		13.2	18	48	17	0.43

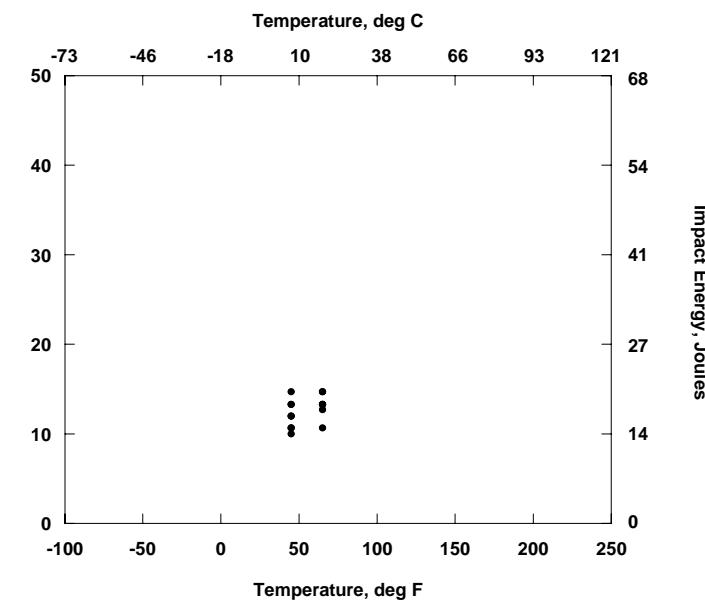
Transition temperature, 85% shear area for specimen

N/A

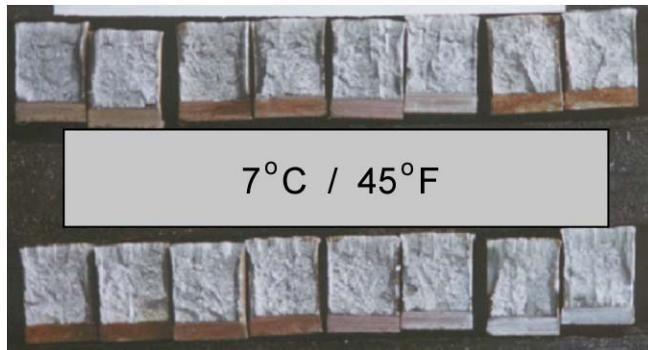
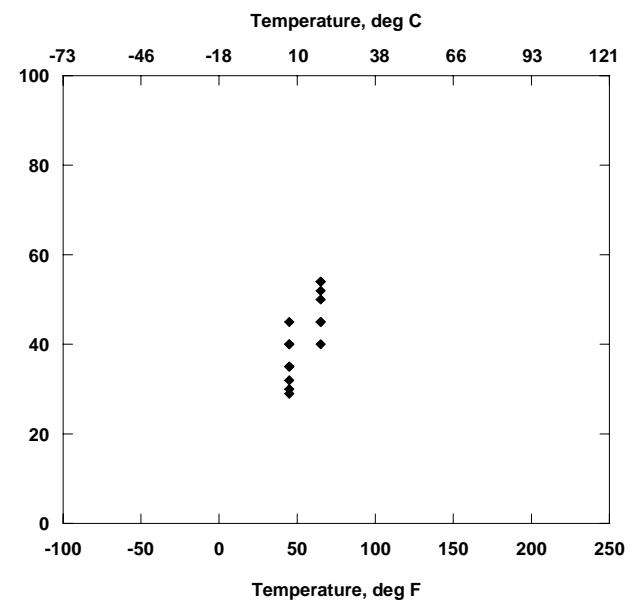
Charpy upper shelf energy, (full size specimen)

N/A

HFC ERW



HFC ERW



Ring flattening test results N/A

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor

Pipe background information

Nominal diameter 16-inch 406 mm
 Nominal wall thickness 0.312-inch 7.9 mm
 Pipe manufacturer US Steel, bought by Camp Hill Corp.
 Year of manufacture Unknown
 Seam weld type HFC ERW, Thermatool
 Reported pipe grade API 5LX-52, possibly cold-expanded

Base metal tensile test results*

Tensile strength	75,000 psi	517 MPa
Yield strength	57,000 psi	393 MPa
Elongation, %	34.0	
Reduction of area, %	45.0	
Mode of failure	Ductile	

Transverse seam weld tensile test results

#1	Failed in base metal	@ 83,000 psi	572 MPa
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*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.253	Unknown year of manufacture
Manganese (Mn)	1.220	Applicable code not known
Phosphorus (P)	0.008	
Sulphur (S)	0.018	
Silicon (Si)	0.038	
Copper (Cu)	0.012	
Tin (Sn)	0.009	
Nickel (Ni)	0.072	
Chromium (Cr)	0.032	
Molybdenum (Mo)	0.008	
Aluminum (Al)	0.004	
Vanadium (V)	0.003	
Niobium (Nb)	0.003	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.005	
CE = C + (Mn/6)	0.4558	
V + Nb + Ti	0.008	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-15	-26	8	11	10	8	0.20
10	-12	10	14	30	10	0.25
35	2	14	19	40	20	0.51
60	16	18	24	55	24	0.61
85	29	22	30	85	26	0.66
110	43	30	41	95	33	0.84
130	54	26	35	100	25	0.64
135	57	27	37	95	29	0.74
160	71	34	46	97	36	0.91
185	85	31	42	100	35	0.89

Transition temperature, 85% shear area for specimen

90 °F

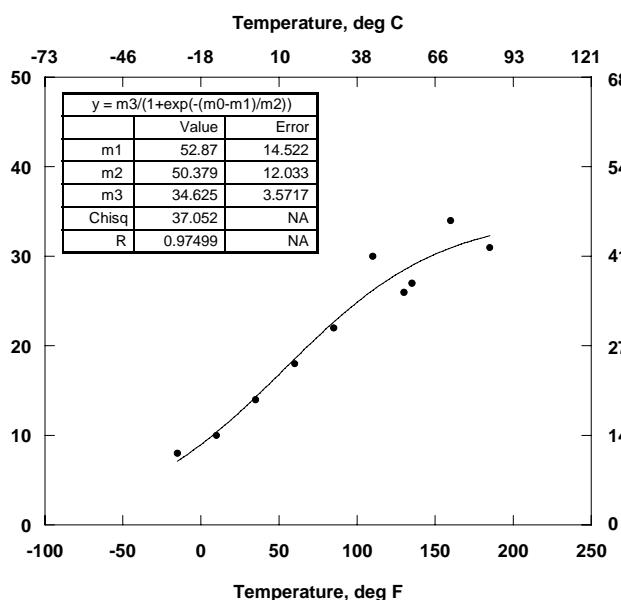
32 °C

Charpy upper shelf energy, (full size specimen)

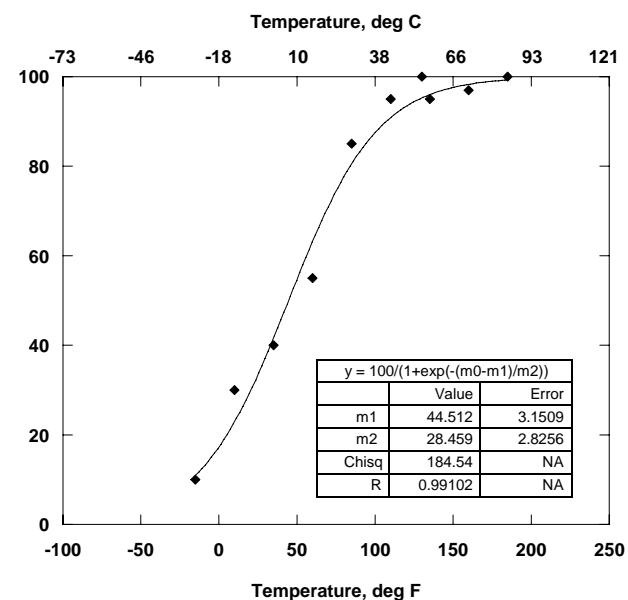
27 ft-lbs

27 Joules

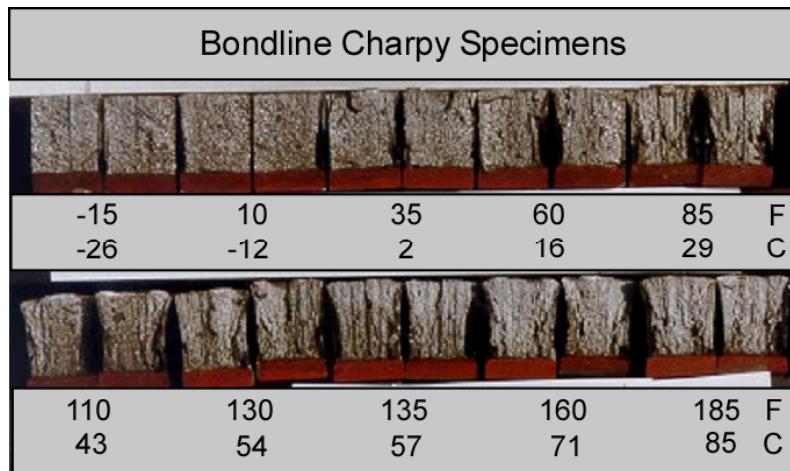
HFC ERW



HFC ERW



Bondline Charpy Specimens



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	Yes	Pipe wall lamination
90°	No	-	No	-	Yes	Seam weld

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor

Pipe background information

Nominal diameter	16-inch	406 mm
Nominal wall thickness	0.312-inch	7.9 mm
Pipe manufacturer	US Steel, bought by Camp Hill Corp.	
Year of manufacture	Unknown	
Seam weld type	HFC ERW, Thermatool	
Reported pipe grade	API 5LX-52, possibly cold-expanded	

Base metal tensile test results*

Tensile strength	73,550 psi	507 MPa
Yield strength	57,050 psi	393 MPa
Elongation, %	33.2	
Reduction of area, %	48.3	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.268	Unknown year of manufacture
Manganese (Mn)	1.205	Applicable code not known
Phosphorus (P)	0.009	
Sulphur (S)	0.018	
Silicon (Si)	0.036	
Copper (Cu)	0.014	
Tin (Sn)	0.015	
Nickel (Ni)	0.013	
Chromium (Cr)	0.038	
Molybdenum (Mo)	0.010	
Aluminum (Al)	0.004	
Vanadium (V)	0.003	
Niobium (Nb)	0.003	
Zirconium (Zr)	0.001	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.006	
CE = C + (Mn/6)	0.4688	
V + Nb + Ti	0.009	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
45	7	14.5	20	40	19	0.48
45	7	16	22	35	16	0.41
45	7	16.5	22	36	17	0.43
45	7	15	20	36	18	0.46
45	7	14.5	20	30	18	0.46
45	7	19	26	58	24	0.61
45	7	18	24	48	20	0.51
45	7	13.5	18	48	17	0.43
<u>Average value</u>		15.9	22	41	19	0.47

Bondline Charpy V-notch impact test results

Test temperature °F	Test temperature °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion	
		ft-lbs	Joules		mils	mm
65	18	18	24	28	21	0.53
65	18	18	24	50	22	0.56
65	18	26	35	71	26	0.66
65	18	25	34	77	26	0.66
65	18	10	14	43	17	0.43
65	18	18	24	59	20	0.51
65	18	18	24	40	20	0.51
65	18	17	23	54	22	0.56
<u>Average value</u>		19	26	53	22	0.55

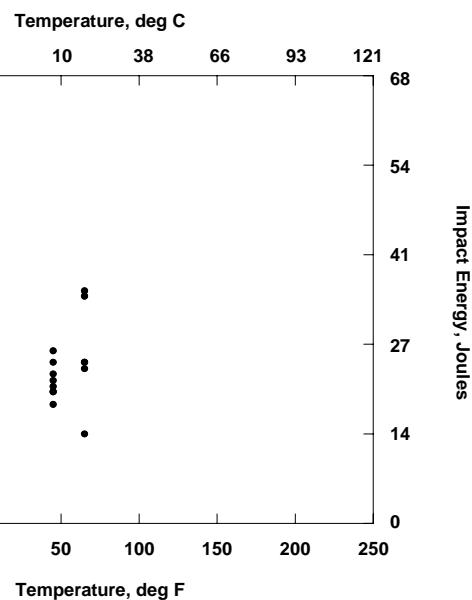
Transition temperature, 85% shear area for specimen

N/A

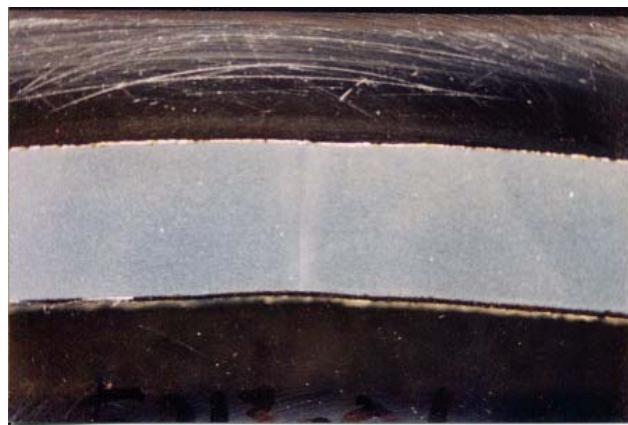
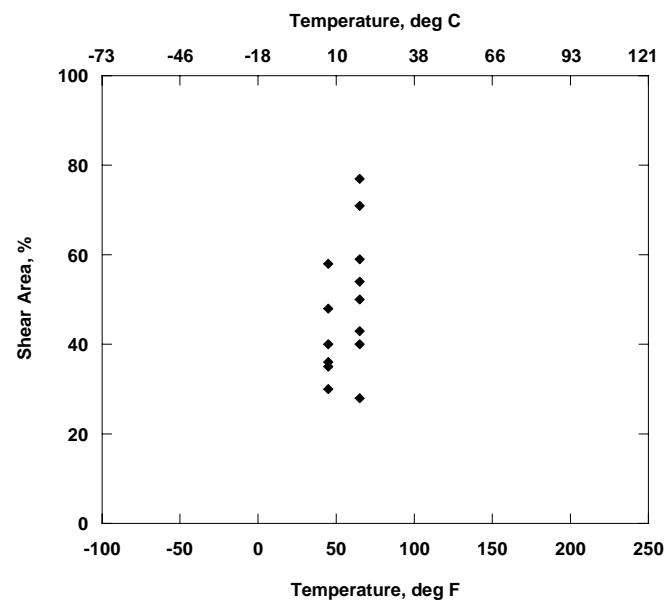
Charpy upper shelf energy, (full size specimen)

N/A

HFC ERW



HFC ERW



Photographs of Charpy specimens were not found in this record

Ring flattening test results N/A

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. This pipe was used for liquid natural gas transmission.

Pipe background information

Nominal diameter 16-inch 406 mm
 Nominal wall thickness 0.312-inch 7.9 mm
 Pipe manufacturer US Steel, bought by Camp Hill Corp.
 Year of manufacture Unknown
 Seam weld type HFC ERW
 Reported pipe grade API 5LX-52, possibly cold-expanded

Base metal tensile test results*

Tensile strength	71,500 psi	493 MPa
Yield strength	55,500 psi	383 MPa
Elongation, %	34.0	
Reduction of area, %	45.0	
Mode of failure	Ductile	

Transverse seam weld tensile test results

#1	Failed in base metal @ 86,000 psi	593 MPa
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*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.259	Unknown year of manufacture
Manganese (Mn)	1.115	Applicable code not known
Phosphorus (P)	0.009	
Sulphur (S)	0.016	
Silicon (Si)	0.035	
Copper (Cu)	0.014	
Tin (Sn)	0.002	
Nickel (Ni)	0.010	
Chromium (Cr)	0.042	
Molybdenum (Mo)	0.006	
Aluminum (Al)	0.006	
Vanadium (V)	0.003	
Niobium (Nb)	0.003	
Zirconium (Zr)	0.000	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0002	
Cobalt (Co)	0.005	
CE = C + (Mn/6)	0.4448	
V + Nb + Ti	0.008	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-15	-26	5	7	0	2	0.05
10	-12	5	7	9	2	0.05
35	2	11	15	24	9	0.23
60	16	12	16	44	12	0.30
85	29	16	22	57	14	0.36
110	43	20	27	74	20	0.51
130	54	23	31	82	22	0.56
135	57	17	23	72	19	0.48
160	71	23	31	94	24	0.61
185	85	22	30	100	22	0.56

Transition temperature, 85% shear area for specimen

142 °F

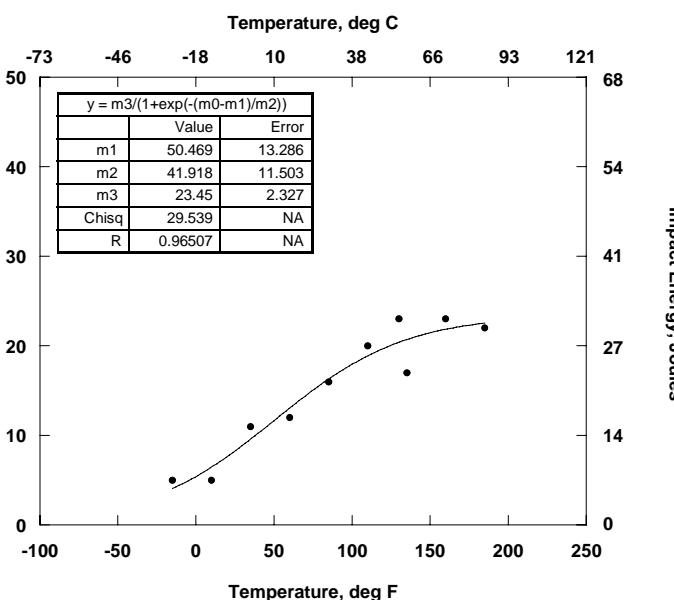
61 °C

Charpy upper shelf energy, (full size specimen)

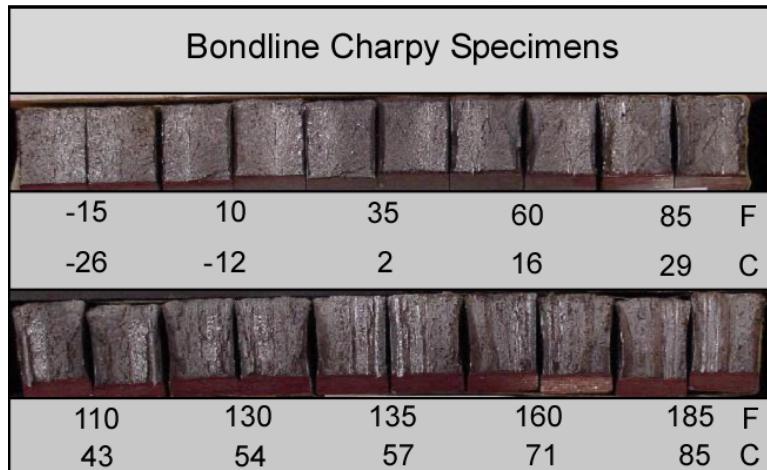
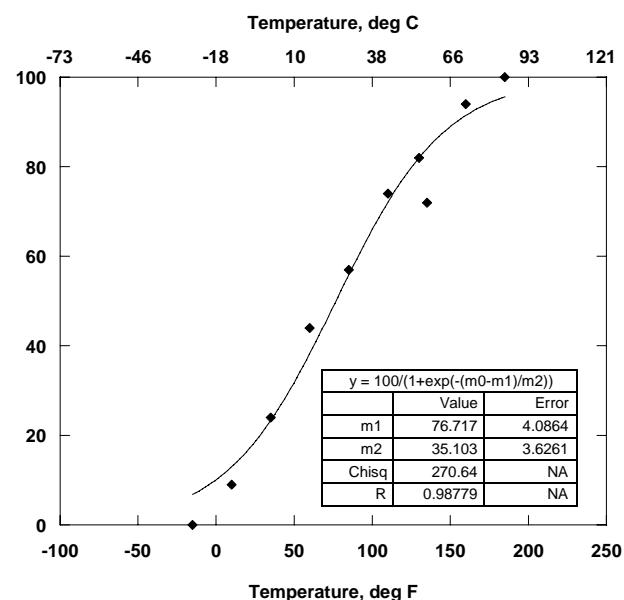
21 ft-lbs

28 Joules

HFC ERW



HFC ERW



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	Yes	Pipe wall lamination
90°	No	-	No	-	Yes	Seam weld

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. This pipe was used for liquid natural gas transmission.

Pipe background information

Nominal diameter	16-inch	406 mm
Nominal wall thickness	0.312-inch	7.9 mm
Pipe manufacturer	US Steel, bought by Camp Hill Corp.	
Year of manufacture	Unknown	
Seam weld type	HFC ERW, Thermatool	
Reported pipe grade	API 5LX-52, possibly cold-expanded	

Base metal tensile test results*

Tensile strength	71,150 psi	491 MPa
Yield strength	56,600 psi	390 MPa
Elongation, %	32.2	
Reduction of area, %	48.6	
Mode of failure	Ductile	

*Average between two transverse tensile tests.

Transverse seam weld tensile test results

#1	Failed in base metal	@ 78,700 psi	543 MPa
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Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.266	Unknown year of manufacture
Manganese (Mn)	1.133	Applicable code not known
Phosphorus (P)	0.010	
Sulphur (S)	0.021	
Silicon (Si)	0.035	
Copper (Cu)	0.037	
Tin (Sn)	0.003	
Nickel (Ni)	0.017	
Chromium (Cr)	0.047	
Molybdenum (Mo)	0.010	
Aluminum (Al)	0.005	
Vanadium (V)	0.003	
Niobium (Nb)	0.003	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.006	
CE = C + (Mn/6)	0.4543	
V + Nb + Ti	0.008	

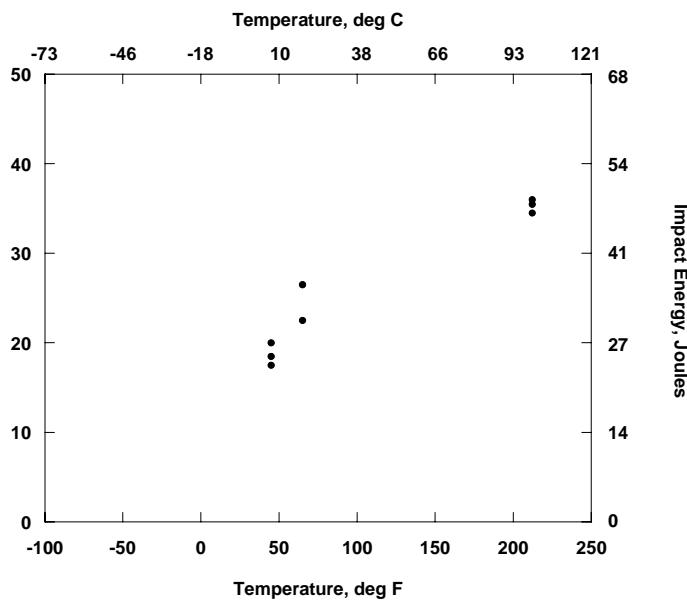
Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
45	7	20	27	40	25	0.64
45	7	18.5	25	40	22	0.56
45	7	17.5	23	48	23	0.58
<u>Average value</u>		18.7	25	43	23	0.59
65	18	22.5	31	68	28	0.71
65	18	26.5	36	54	32	0.81
65	18	26.5	36	62	26	0.66
<u>Average value</u>		25.2	34	61	29	0.73

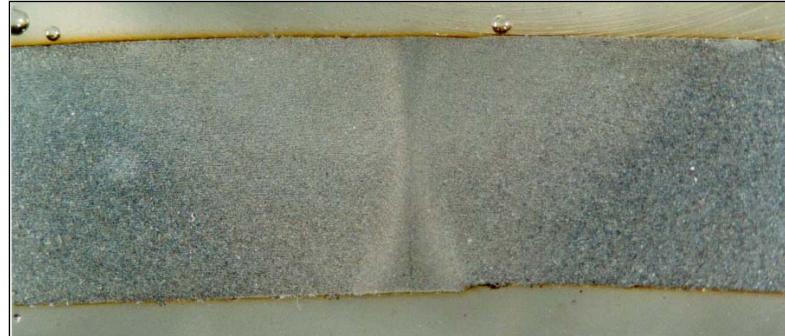
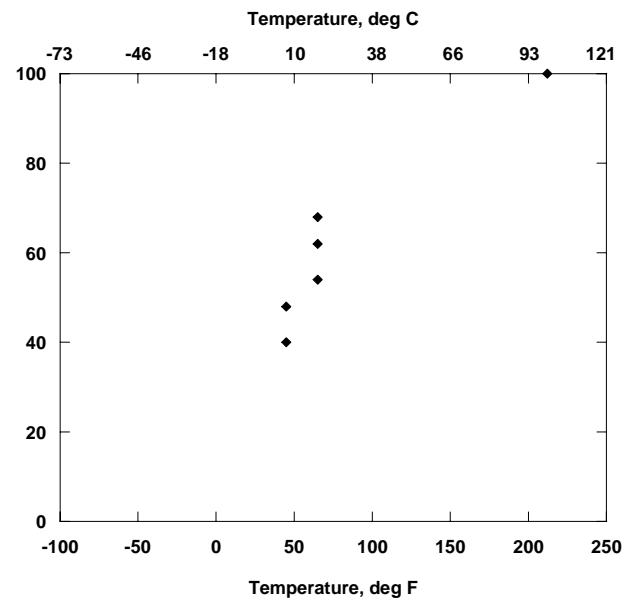
Bondline Charpy V-notch impact test results

Test temperature °F	°C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		<u>Shear area percent</u>	<u>Lateral expansion</u>	
		ft-lbs	Joules		mils	mm
212	100	36	49	100	39	0.99
212	100	34.5	47	100	36	0.91
212	100	35.5	48	100	45	1.14
<u>Average value</u>		35.3	48	100	40	1.01
<u>Transition temperature, 85% shear area for specimen</u>				N/A		
<u>Charpy upper shelf energy, (full size specimen)</u>				N/A		

HFC ERW



HFC ERW



Photographs of Charpy specimens were not found in this record

Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	Yes	Seam weld, OD

General notes and observations for this pipe section:

This pipe section failed in the seam weld during a hydrostatic test, upstream from the area of material property testing. Failure pressure was not reported.

Pipe background information

Nominal diameter 16-inch 406 mm
 Nominal wall thickness 0.312-inch 7.9 mm
 Pipe manufacturer Lone Star, Yoder Mill
 Year of manufacture Unknown
 Seam weld type LF ERW
 Reported pipe grade API 5LX-52, non-expanded

Base metal tensile test results*

Tensile strength 78,500 psi 541 MPa
 Yield strength 59,100 psi 407 MPa
 Elongation, % 30.1
 Reduction of area, % 44.9
 Mode of failure Ductile

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.277	Unknown year of manufacture
Manganese (Mn)	1.220	Applicable code not known
Phosphorus (P)	0.027	
Sulphur (S)	0.020	
Silicon (Si)	0.014	
Copper (Cu)	0.345	
Tin (Sn)	0.010	
Nickel (Ni)	0.040	
Chromium (Cr)	0.040	
Molybdenum (Mo)	0.015	
Aluminum (Al)	0.005	
Vanadium (V)	0.004	
Niobium (Nb)	0.004	
Zirconium (Zr)	0.001	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.013	
CE = C + (Mn/6)	0.4803	
V + Nb + Ti	0.010	

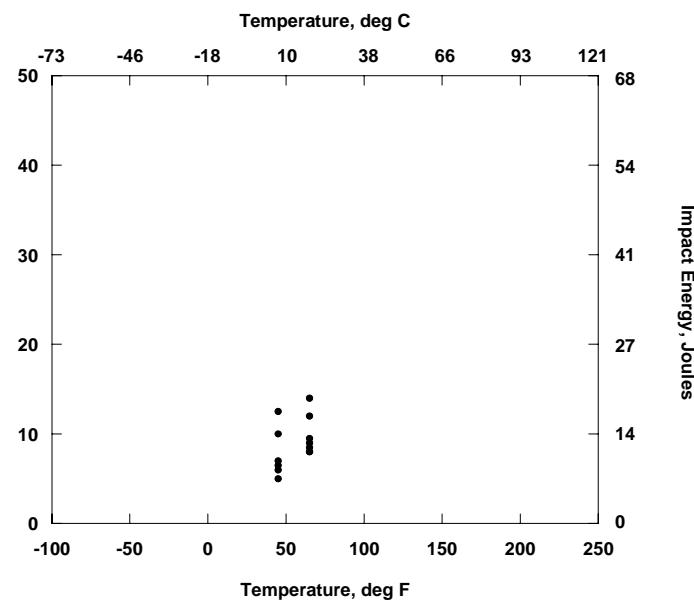
Bondline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
45	7	6.5	9	7	7	0.18
45	7	7	9	15	8	0.20
45	7	6	8	15	7	0.18
45	7	10	14	12	11	0.28
45	7	5	7	15	8	0.20
45	7	12.5	17	12	16	0.41
45	7	12.5	17	15	16	0.41
45	7	12.5	17	12	16	0.41
<u>Average value</u>		9	12	13	11	0.28

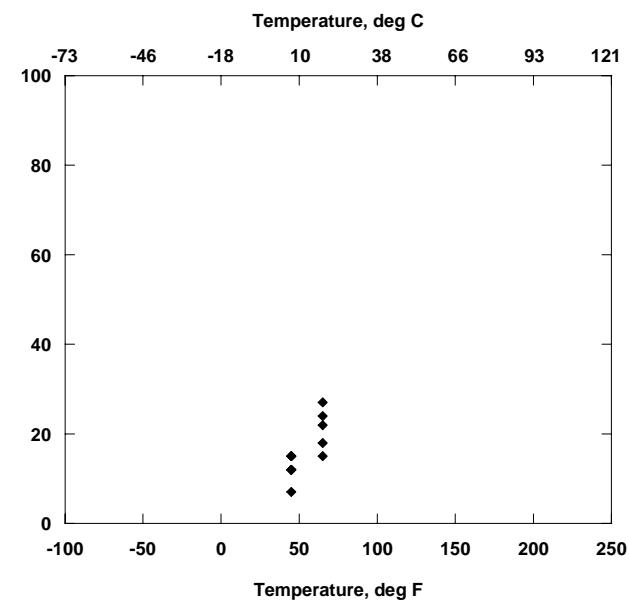
Bondline Charpy V-notch impact test results

Test temperature °F	Test temperature °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion	
		ft-lbs	Joules		mils	mm
65	18	14	19	22	18	0.46
65	18	14	19	24	16	0.41
65	18	8	11	15	12	0.30
65	18	9.5	13	15	11	0.28
65	18	9	12	27	13	0.33
65	18	8	11	18	12	0.30
65	18	8.5	12	18	11	0.28
65	18	12	16	18	16	0.41
<u>Average value</u>		10.4	14	20	14	0.35
<u>Transition temperature, 85% shear area for specimen</u>				N/A		
<u>Charpy upper shelf energy, (full size specimen)</u>				N/A		

LF ERW



LF ERW



Photographs of Charpy specimens were not found in this record

Ring flattening test results N/A

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. This pipe was used for liquid natural gas transmission.

Pipe background information

Nominal diameter 16-inch 406 mm
 Nominal wall thickness 0.312-inch 7.9 mm
 Pipe manufacturer Lone Star, Yoder Mill
 Year of manufacture Unknown
 Seam weld type LF ERW
 Reported pipe grade API 5LX-52, non-expanded

Base metal tensile test results*

Tensile strength	85,720 psi	591 MPa
Yield strength	66,250 psi	457 MPa
Elongation, %	27.5	
Reduction of area, %	42.5	
Mode of failure	Ductile	

Transverse seam weld tensile test results

#1	Failed in base metal @ 81,000 psi	558 MPa
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*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.376	Unknown year of manufacture
Manganese (Mn)	1.240	Applicable code not known
Phosphorus (P)	0.030	
Sulphur (S)	0.018	
Silicon (Si)	0.015	
Copper (Cu)	0.402	
Tin (Sn)	0.013	
Nickel (Ni)	0.050	
Chromium (Cr)	0.030	
Molybdenum (Mo)	0.015	
Aluminum (Al)	0.002	
Vanadium (V)	0.003	
Niobium (Nb)	0.003	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0.000	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.014	
CE = C + (Mn/6)	0.5822	
V + Nb + Ti	0.008	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-15	-26	9.5	13	0	5	0.13
10	-12	9.5	13	5	3	0.08
35	2	11	15	15	12	0.30
60	16	15	20	30	8	0.20
85	29	19	26	45	16	0.41
110	43	27	37	60	22	0.56
122	50	31.5	43	80	22	0.56
135	57	31	42	95	27	0.69
160	71	35.5	48	98	27	0.69
185	85	35	47	98	28	0.71

Transition temperature, 85% shear area for specimen

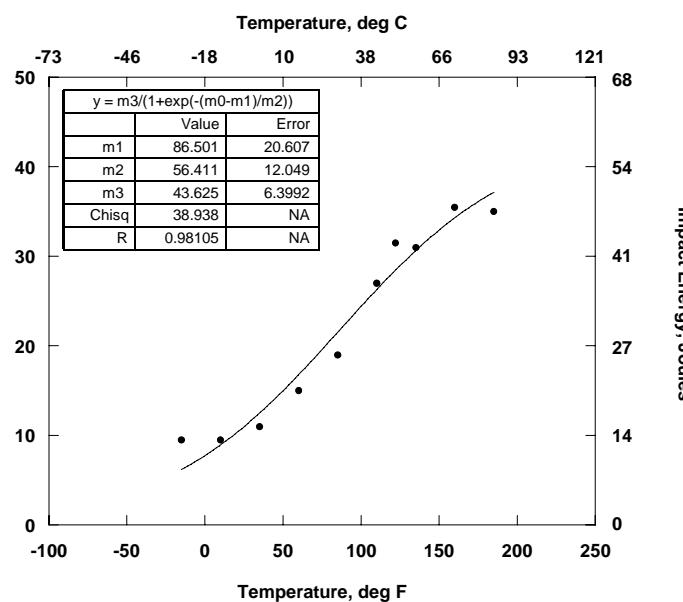
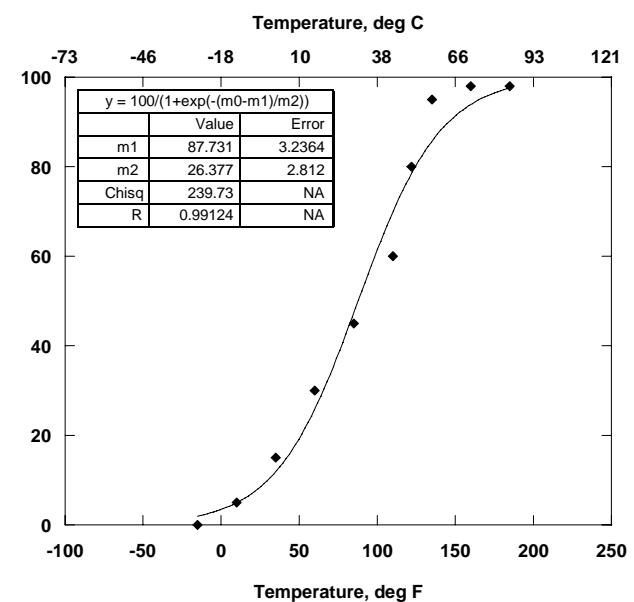
128 °F

53 °C

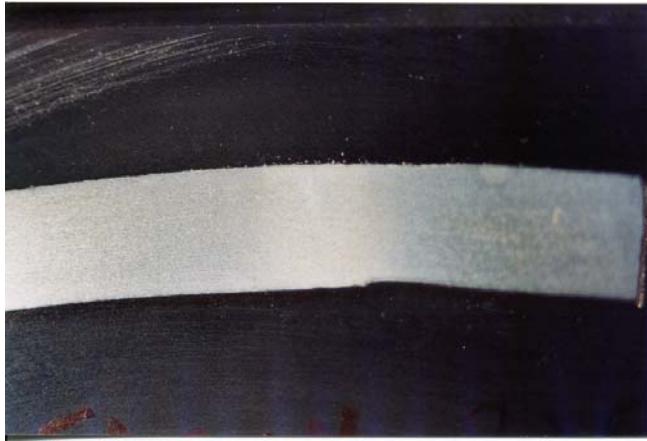
Charpy upper shelf energy, (full size specimen)

31 ft-lbs

42 Joules

LF ERW**LF ERW**

Photographs of Charpy specimens were not found in this record


Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. This pipe section was removed from service when SCC colonies were found in the base metal.

Pipe background information

Nominal diameter 16-inch 406 mm
 Nominal wall thickness 0.312-inch 7.9 mm
 Pipe manufacturer Lone Star, Yoder Mill
 Year of manufacture Unknown
 Seam weld type LF ERW
 Reported pipe grade API 5LX-52, non-expanded

Base metal tensile test results*

Tensile strength	89,000 psi	614 MPa
Yield strength	65,500 psi	452 MPa
Elongation, %	31.0	
Reduction of area, %	44.5	
Mode of failure	Ductile	

Transverse seam weld tensile test results

#1	Failed in base metal @ 91,000 psi	627 MPa
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*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.263	Unknown year of manufacture
Manganese (Mn)	1.195	Applicable code not known
Phosphorus (P)	0.036	
Sulphur (S)	0.015	
Silicon (Si)	0.014	
Copper (Cu)	0.338	
Tin (Sn)	0.009	
Nickel (Ni)	0.050	
Chromium (Cr)	0.050	
Molybdenum (Mo)	0.017	
Aluminum (Al)	0.004	
Vanadium (V)	0.003	
Niobium (Nb)	0.003	
Zirconium (Zr)	0.000	
Titanium (Ti)	0.002	
Boron (B)	0.000	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.013	
CE = C + (Mn/6)	0.4687	
V + Nb + Ti	0.009	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
10	-12	4	5	12	2	0.05
35	2	4	5	12	3	0.08
60	16	12.5	17	25	12	0.30
85	29	12.5	17	43	12	0.30
110	43	11	15	53	12	0.30
135	57	19.5	26	53	18	0.46
160	71	11	15	93	26	0.66
185	85	23.5	32	100	27	0.69
210	99	24	33	100	26	0.66

Transition temperature, 85% shear area for specimen

155 °F

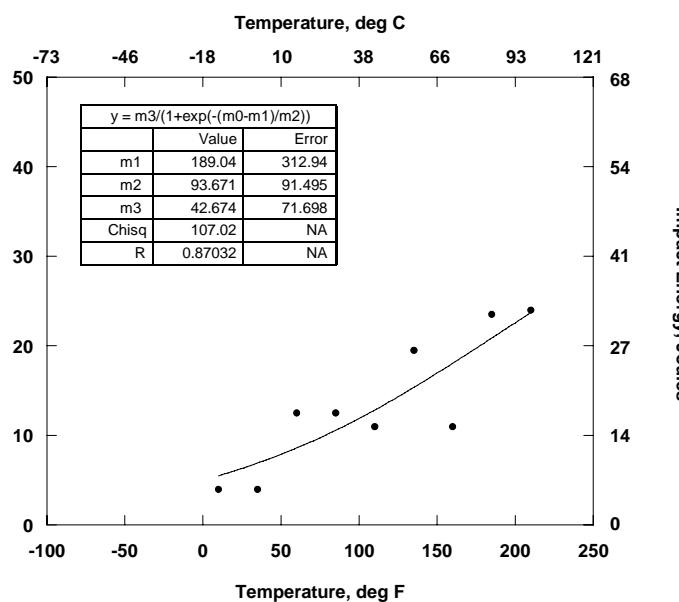
68 °C

Charpy upper shelf energy, (full size specimen)

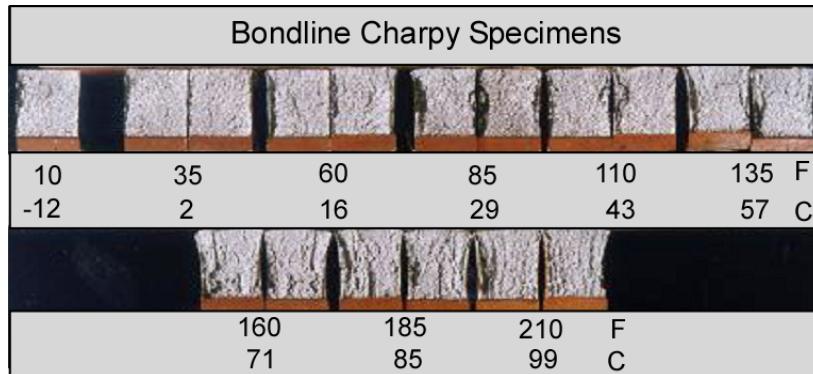
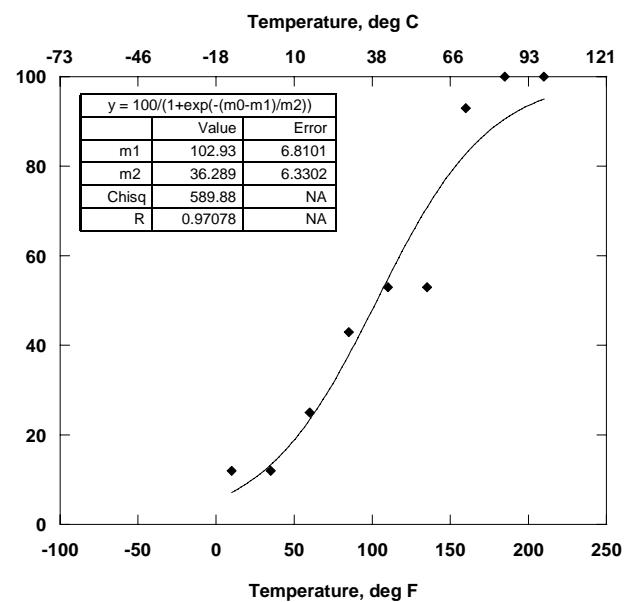
20 ft-lbs

27 Joules

LF ERW



LF ERW



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	Yes	Seam weld

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor.

Pipe background information

Nominal diameter	20-inch	508 mm
Nominal wall thickness	0.312-inch	7.9 mm
Pipe manufacturer	A. O. Smith Corp.	
Year of manufacture	1951-1952	
Seam weld type	Flash Weld	
Reported pipe grade	API 5LX-52, cold-expanded	

Tensile test results

Base metal tensile testing was conducted on this pipe sample by the client to determine if the pipe section met API 5LX-52 yield and tensile strength requirements. Tensile testing across the seam weld was also conducted. These results were not presented to CC Technologies.

Chemical analysis results

Base metal chemical analysis was conducted on this pipe sample by the client to determine if the pipe section met the requirements for API 5LX-52, cold-expanded pipe for the applicable year of manufacture. These results were not presented to CC Technologies.

Flash centerline Charpy V-notch impact test results

Test temperature °F °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
	ft-lbs	Joules			
25 -4	1.5	2	6	Not reported	
50 10	3	4	9		
75 24	3.5	5	16		
100 38	7	9	31		
125 52	7.5	10	47		
150 66	8.5	12	68		
175 79	11.5	16	83		
200 93	14.5	20	94		
225 107	13	18	98		
<u>Transition temperature, 85% shear area for specimen</u>		175	°F	79 °C	
<u>Charpy upper shelf energy, (full size specimen)</u>		12	ft-lbs	16 Joules	

HAZ Charpy V-notch impact test results

Test temperature °F °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
	ft-lbs	Joules			
-25 -32	4	5	0	Not reported	
0 -18	4.5	6	6		
25 -4	3	4	27		
50 10	3.5	5	30		
75 24	7	9	37		
100 38	10	14	54		
125 52	10	14	88		
150 66	11.5	16	89		
175 79	10	14	96		
200 93	14.5	20	100		
<u>Transition temperature, 85% shear area for specimen</u>		125	°F	52 °C	
<u>Charpy upper shelf energy, (full size specimen)</u>		10	ft-lbs	14 Joules	

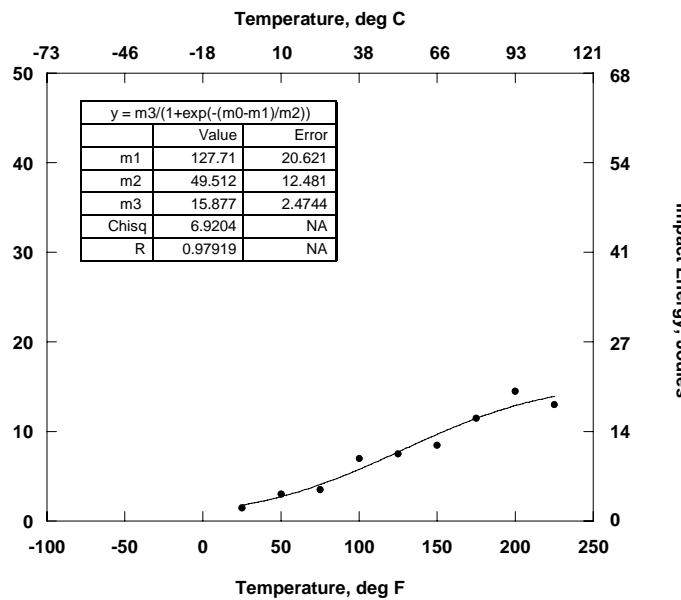
Base metal Charpy V-notch impact test results

Test temperature °F	Test temperature °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion	
		ft-lbs	Joules		mils	mm
-25	-32	6	8	0		Not reported
0	-18	4.5	6	6		
25	-4	10.5	14	16		
50	10	11	15	35		
75	24	16.5	22	71		
100	38	20.5	28	83		
125	52	22	30	97		
150	66	23	31	99		
175	79	22	30	100		

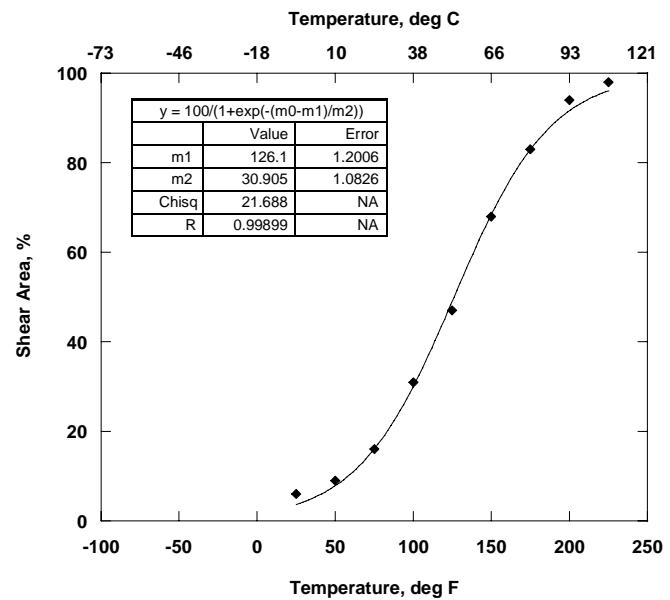
Transition temperature, 85% shear area for specimen 110 °F 43 °C
Charpy upper shelf energy, (full size specimen) 21 ft-lbs 28 Joules

1951-1952, Flash Weld

Impact Energy, ft-lb

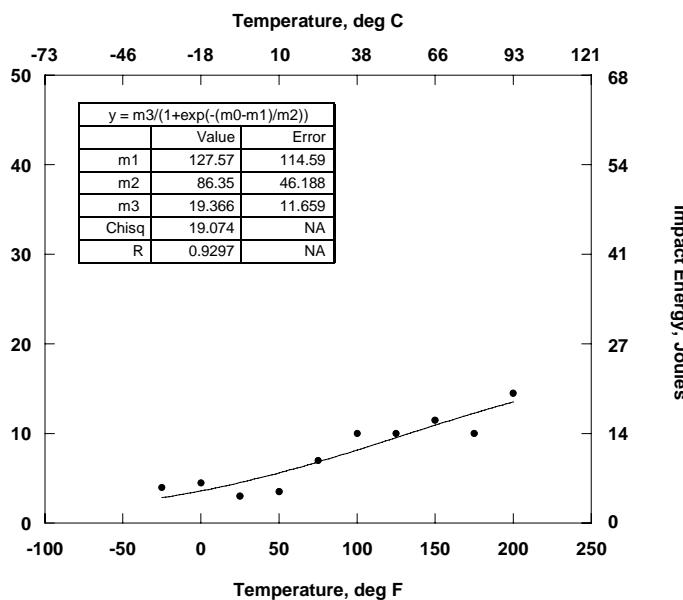


1951-1952, Flash Weld

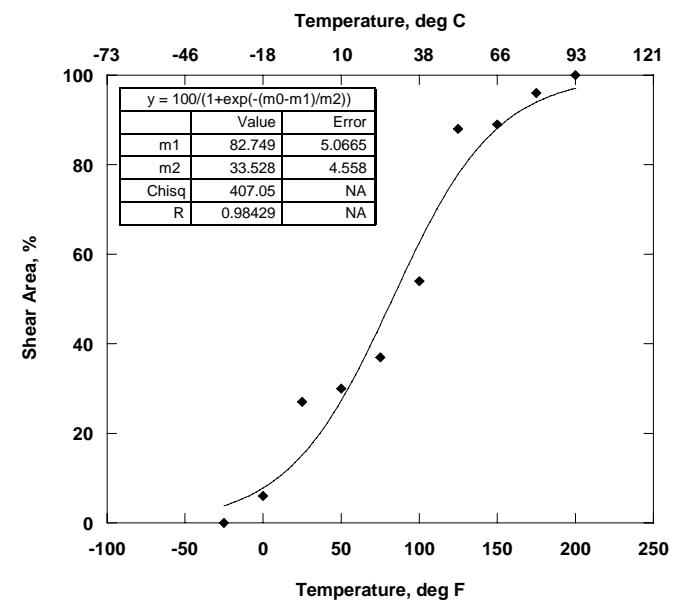


1951-1952, Flash Weld HAZ

Impact Energy, ft-lb

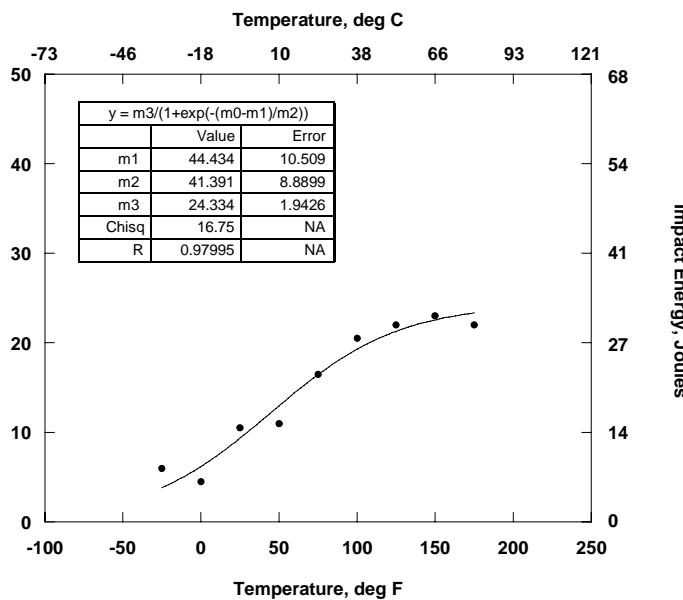


1951-1952, Flash Weld HAZ

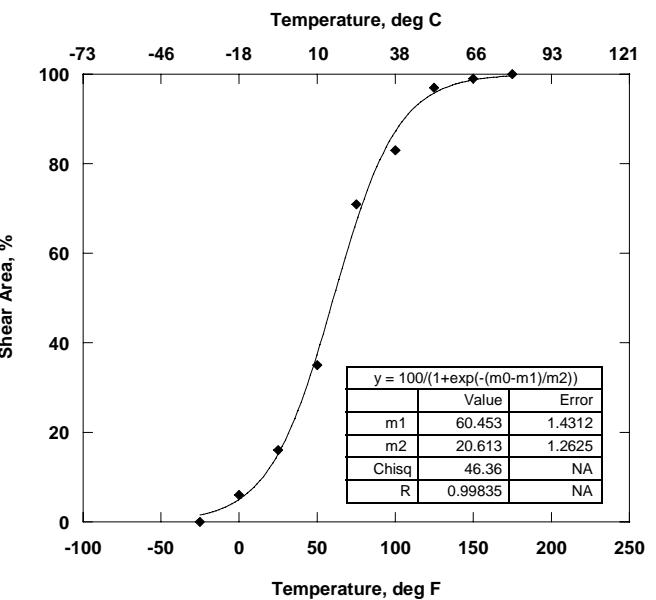


1951-1952, Flash Weld Base Metal

Impact Energy, ft-lb



1951-1952, Flash Weld Base Metal



Charpy specimens were not returned for photo documentation

Ring flattening test results N/A

General notes and observations for this pipe section:

The background information and testing results for this pipe section were the result of a collaborative effort between several industry clients and CC Technologies.

Pipe background information

Nominal diameter	20-inch	508 mm
Nominal wall thickness	0.312-inch	7.9 mm
Pipe manufacturer	Kaiser Steel Corporation	
Year of manufacture	Early 1960's	
Seam weld type	SSAW	
Reported pipe grade	API 5LX-52, non-expanded	

Tensile test results

Base metal tensile testing was conducted on this pipe sample by the client to determine if the pipe section met API 5LX-52 yield and tensile strength requirements. Tensile testing across the seam weld was also conducted. These results were not presented to CC Technologies.

Chemical analysis results

Base metal chemical analysis was conducted on this pipe sample by the client to determine if the pipe section met the requirements for API 5LX-52, cold-expanded pipe for the applicable year of manufacture. These results were not presented to CC Technologies.

Weld metal Charpy V-notch impact test results

Test temperature °F °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
	ft-lbs	Joules			
10 -12	2.5	3	0	Not reported	
35 2	4	5	2		
60 16	12	16	14		
85 29	16	22	17		
110 43	20	27	38		
135 57	29	39	72		
160 71	30.5	41	76		
185 85	34.5	47	89		
205 96	35	47	100		
230 110	35	47	100		
<u>Transition temperature, 85% shear area for specimen</u>		175 °F		79 °C	
<u>Charpy upper shelf energy, (full size specimen)</u>		33 ft-lbs		45 Joules	

HAZ Charpy V-notch impact test results

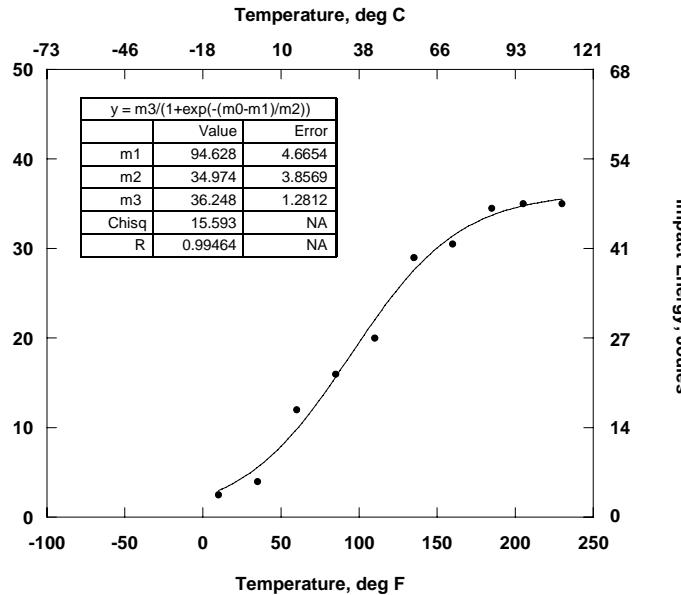
Test temperature °F °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
	ft-lbs	Joules			
10 -12	9	12	0	Not reported	
35 2	10	14	14		
60 16	17.5	24	17		
85 29	19	26	21		
110 43	23	31	29		
135 57	25	34	40		
160 71	38	52	40		
185 85	42	57	97		
205 96	42	57	100		
230 110	43	58	100		
<u>Transition temperature, 85% shear area for specimen</u>		175 °F		79 °C	
<u>Charpy upper shelf energy, (full size specimen)</u>		41 ft-lbs		56 Joules	

Base metal Charpy V-notch impact test results

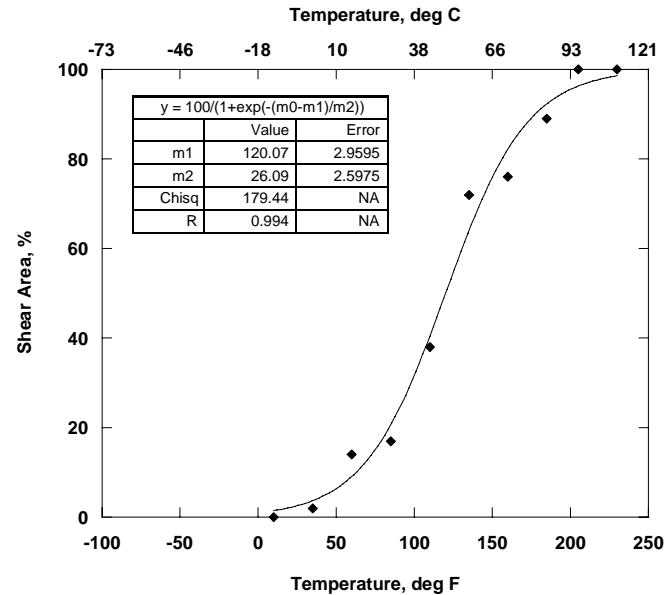
Test temperature °F	°C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion	
		ft-lbs	Joules		mils	mm
-10	-23	7	9	0		
10	-12	9	12	0		
35	2	10.5	14	10		
60	16	15	20	17		
85	29	18	24	26		
110	43	30	41	84		
135	57	32	43	100		
160	71	34	46	100		
185	85	33.5	45	100		
<u>Transition temperature, 85% shear area for specimen</u>		110	°F	43	°C	
<u>Charpy upper shelf energy, (full size specimen)</u>		27	ft-lbs	37	Joules	

Early 1960's, SAW

Impact Energy, ft-lb

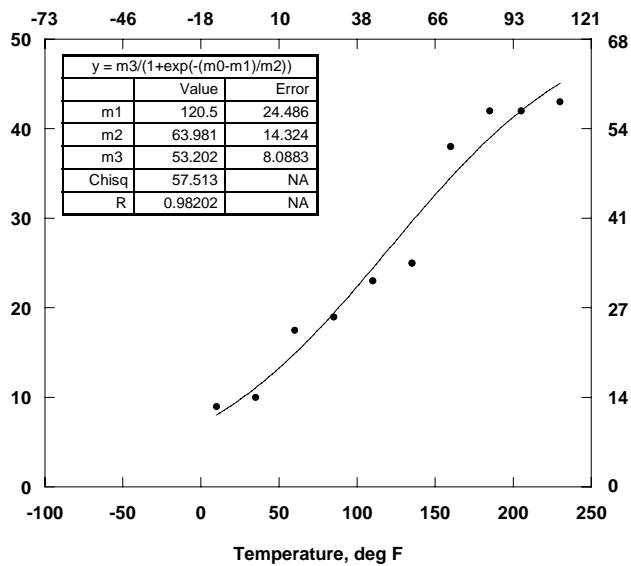


Early 1960's, SAW



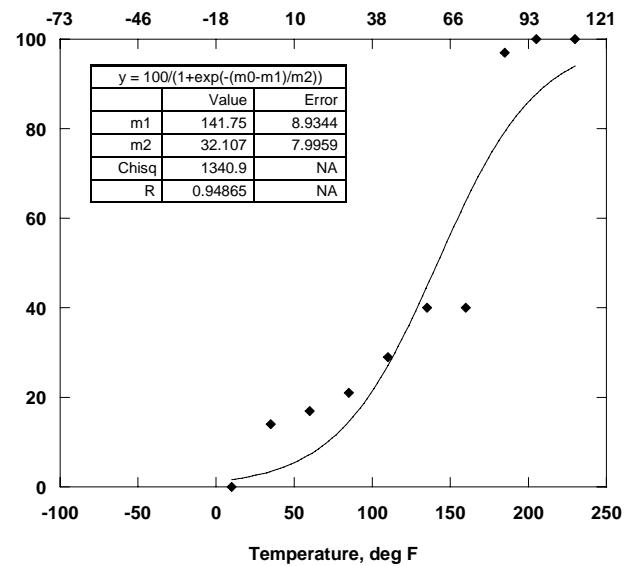
Early 1960's, SSAW HAZ

Temperature, deg C



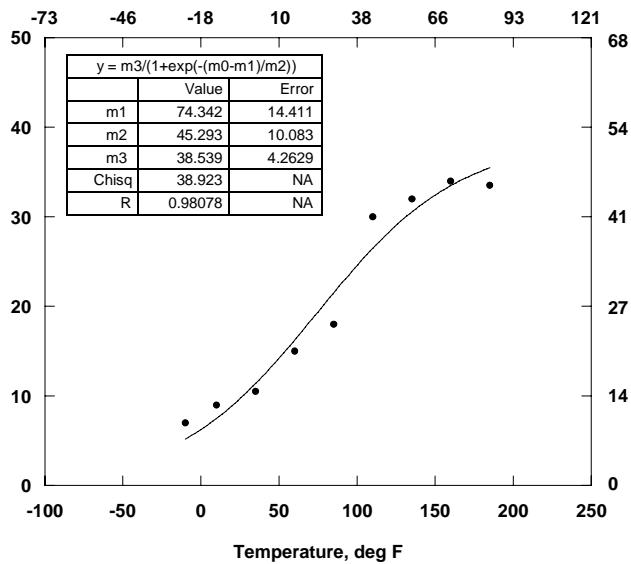
Early 1960's, SSAW HAZ

Temperature, deg C



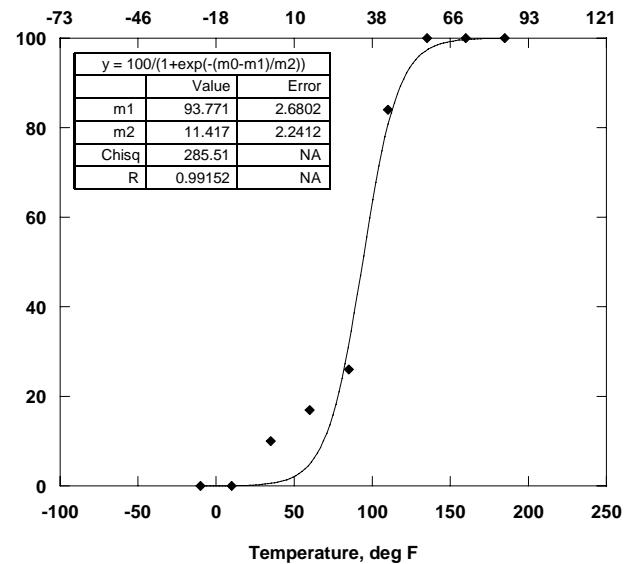
Early 1960's, SSAW Base Metal

Temperature, deg C



Early 1960's, SSAW Base Metal

Temperature, deg C



Charpy specimens were not returned for photo documentation

Ring flattening test results N/A

General notes and observations for this pipe section:

The background information and testing results for this pipe section were the result of a collaborative effort between several industry clients and CC Technologies.

Pipe background information

Nominal diameter	20-inch	508 mm
Nominal wall thickness	0.312-inch	7.9 mm
Pipe manufacturer	Youngstown Steel & Tube, Final mill	
Year of manufacture	1951-1952	
Seam weld type	d.c. ERW	
Reported pipe grade	API 5LX-52, probably cold-expanded	

Tensile test results

Base metal tensile testing was conducted on this pipe sample by the client to determine if the pipe section met API 5LX-52 yield and tensile strength requirements. Tensile testing across the seam weld was also conducted. These results were not presented to CC Technologies.

Chemical analysis results

Base metal chemical analysis was conducted on this pipe sample by the client to determine if the pipe section met the requirements for API 5LX-52, cold-expanded pipe for the applicable year of manufacture. These results were not presented to CC Technologies.

Bondline Charpy V-notch impact test results

Test temperature °F °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
	ft-lbs	Joules			
10 -12	3	4	0	Not reported	
35 2	4.5	6	31		
60 16	6	8	42		
85 29	7	9	49		
110 43	5.5	7	62		
135 57	8.5	12	65		
160 71	10	14	70		
185 85	7	9	77		
205 96	7	9	87		
230 110	7	9	94		

Transition temperature, 85% shear area for specimen 185 °F 85 °C
Charpy upper shelf energy, (full size specimen) 7 ft-lbs 9 Joules

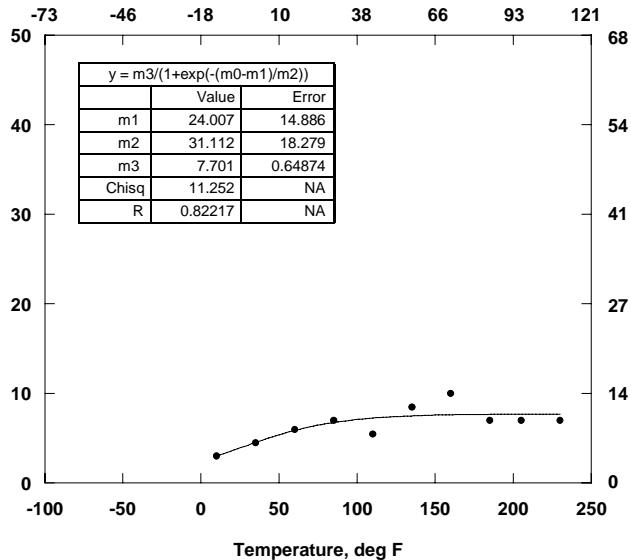
Base metal Charpy V-notch impact test results

Test temperature °F °C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion mils mm	
	ft-lbs	Joules			
-60 -51	1	1	0	Not reported	
-40 -40	1.5	2	0		
-15 -26	3	4	17		
10 -12	4	5	33		
16 -9	8	11	74		
22 -6	10.5	14	88		
35 2	10.5	14	100		
60 16	13.5	18	100		
85 29	14.5	20	100		

Transition temperature, 85% shear area for specimen 20 °F -7 °C
Charpy upper shelf energy, (full size specimen) 11 ft-lbs 15 Joules

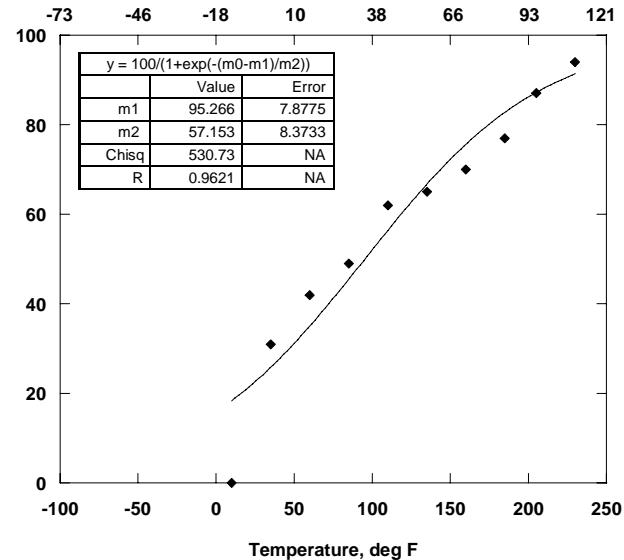
1951-1952, d.c. ERW

Temperature, deg C



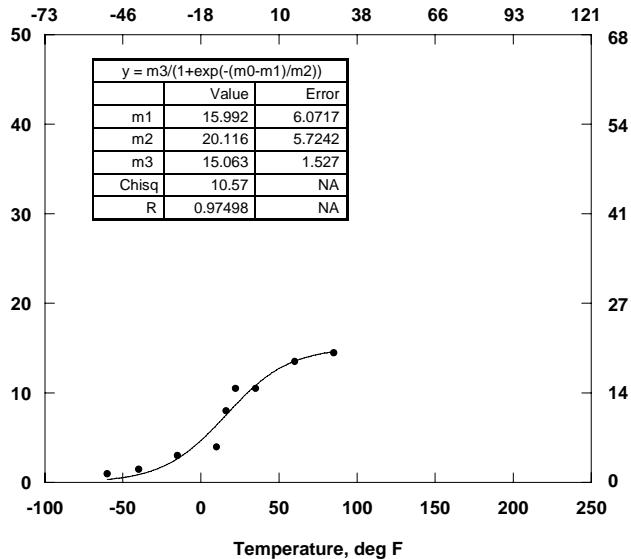
1951-1952, d.c. ERW

Temperature, deg C



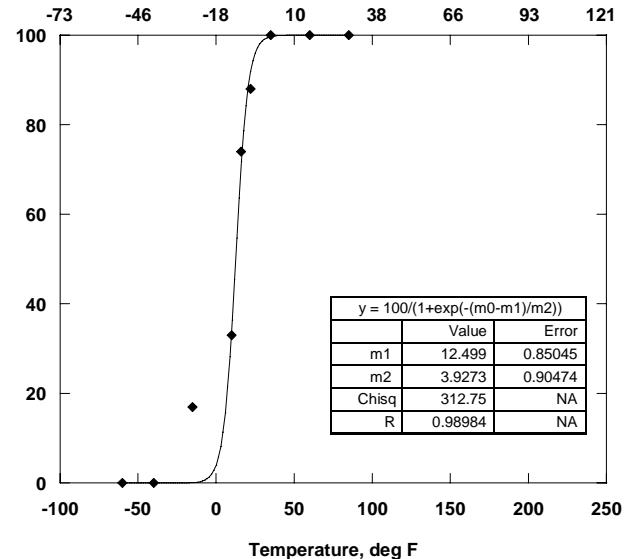
1951-1952, d.c. ERW Base Metal

Temperature, deg C



1951-1952, d.c. ERW Base Metal

Temperature, deg C



Charpy specimens were not returned for photo documentation

Ring flattening test results N/A

General notes and observations for this pipe section:

The background information and testing results for this pipe section were the result of a collaborative effort between several industry clients and CC Technologies.

Pipe background information

Nominal diameter 8-inch 203 mm
 Nominal wall thickness 0.250-inch 6.4 mm
 Pipe manufacturer Youngstown Sheet & Tube
 Year of manufacture Reported as early 1940's
 Seam weld type Lap Weld
 Reported pipe grade API 5L Gr. B, non-expanded

Base metal tensile test results*

Tensile strength 51,800 psi 357 MPa
 Yield strength 36,100 psi 249 MPa
 Elongation, % 30.0
 Reduction of area, % 44.5
 Mode of failure Ductile

Transverse seam weld tensile test results

#1 Failed in Lap @ 49,050 psi 338 MPa
 #2 Failed in Lap @ 42,350 psi 292 MPa

*Average between two transverse tensile tests.

Lap area chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>
Carbon (C)	0.190
Manganese (Mn)	0.980
Phosphorus (P)	0.034
Sulphur (S)	0.020
Silicon (Si)	0.032
Copper (Cu)	0.060
Tin (Sn)	0.004
Nickel (Ni)	0.008
Chromium (Cr)	0.021
Molybdenum (Mo)	0.010
Aluminum (Al)	0.018
Vanadium (V)	0.002
Niobium (Nb)	0.002
Zirconium (Zr)	0
Titanium (Ti)	0.001
Boron (B)	0
Calcium (Ca)	0.0001
Cobalt (Co)	0.01
CE = C + (Mn/6)	0.3533
V + Nb + Ti	0.005

Base metal max. allow (Wt %)

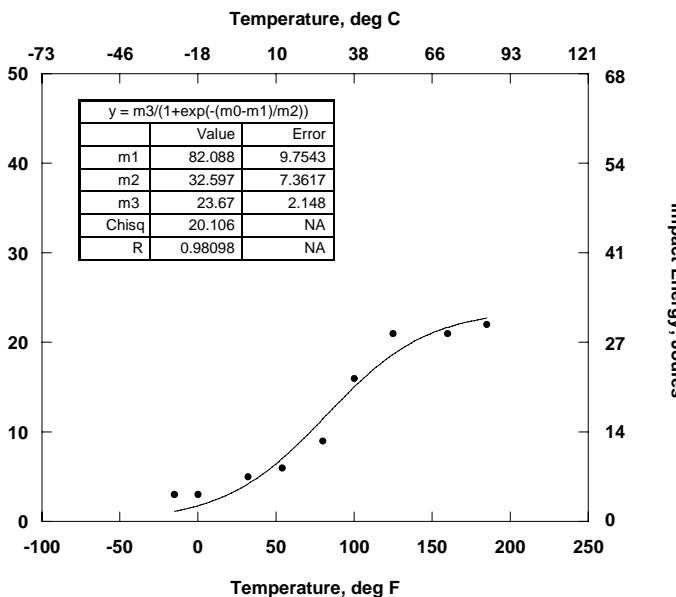
Unknown year of manufacture
 Applicable code not known

Lap mid-point Charpy V-notch impact test results

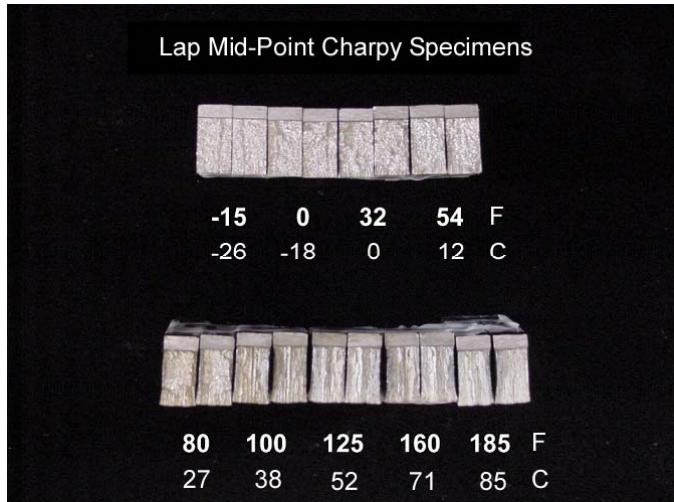
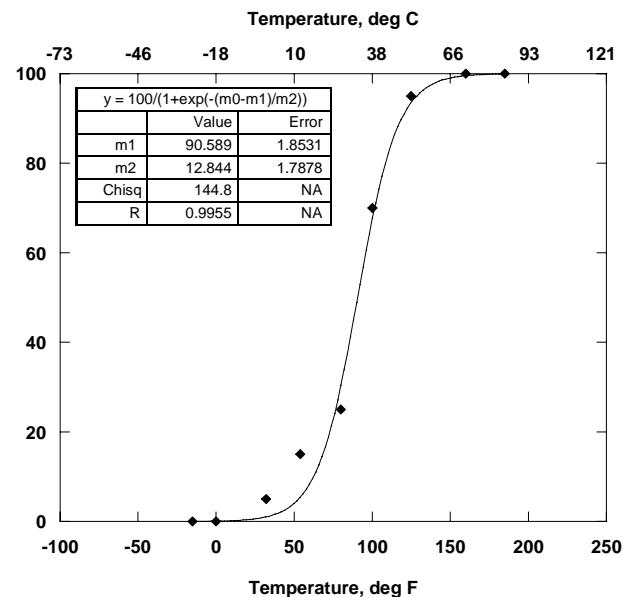
<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-15	-26	3	4	0	2	0.05
0	-18	3	4	0	2	0.05
32	0	5	7	5	4	0.10
54	12	6	8	15	6	0.15
80	27	9	12	25	12	0.30
100	38	16	22	70	18	0.46
125	52	21	28	95	18	0.46
160	71	21	28	100	22	0.56
185	85	22	30	100	21	0.53

Transition temperature, 85% shear area for specimen 120 °F 49 °C
Charpy upper shelf energy, (full size specimen) 20 ft-lbs 27 Joules

Early 1940's Lap Weld



Early 1940's, Lap Weld



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	Yes	Lap

General notes and observations for this pipe section:

This pipe section was removed downstream from a rupture. The rupture occurred in the Lap during a hydrostatic test. Failure pressure was not reported and the failed section was not submitted.

Pipe background information

Nominal diameter 12-inch 305 mm
 Nominal wall thickness 0.233-inch 5.9 mm
 Pipe manufacturer Unknown
 Year of manufacture 1925 – 1928
 Seam weld type Lap Weld
 Reported pipe grade Probably API 5L Gr. B

Base metal tensile test results*

Tensile strength 51,900 psi 358 MPa
 Yield strength 32,200 psi 222 MPa
 Elongation, % 15.5
 Reduction of area, % 18.4
 Mode of failure Ductile

Transverse seam weld tensile test results

#1	<u>Failed in base metal</u> @ 52,750 psi	364 MPa
#2	<u>Failed in Lap</u> @ 48,900 psi	337 MPa

*Average between two transverse tensile tests.

Lap area chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.097	Unknown year of manufacture
Manganese (Mn)	0.434	Applicable code not known
Phosphorus (P)	0.029	
Sulphur (S)	0.037	
Silicon (Si)	0.022	
Copper (Cu)	0.013	
Tin (Sn)	0.002	
Nickel (Ni)	0.006	
Chromium (Cr)	0.007	
Molybdenum (Mo)	0.003	
Aluminum (Al)	0.012	
Vanadium (V)	0	
Niobium (Nb)	0.002	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.005	
CE = C + (Mn/6)	0.1693	
V + Nb + Ti	0.004	

Lap mid-point Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-4	-20	5	7	0	10	0.25
32	0	15	20	0	4	0.10
73	23	6	8	10	14	0.36
104	40	11	15	15	24	0.61
140	60	28	38	50	47	1.19
158	70	59	80	85	70	1.78
176	80	64	87	100	76	1.93
176	80	64	87	100	69	1.75
212	100	60	81	100	65	1.65
248	120	60	81	100	76	1.93

Transition temperature, 85% shear area for specimen

150 °F

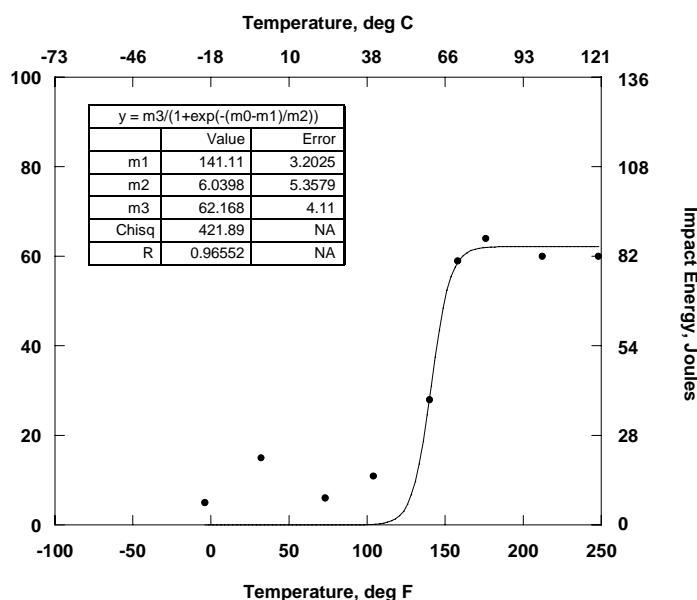
66 °C

Charpy upper shelf energy, (full size specimen)

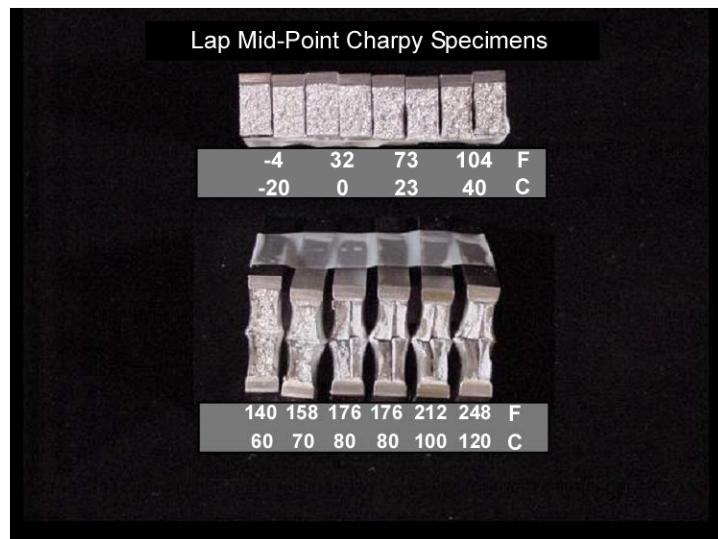
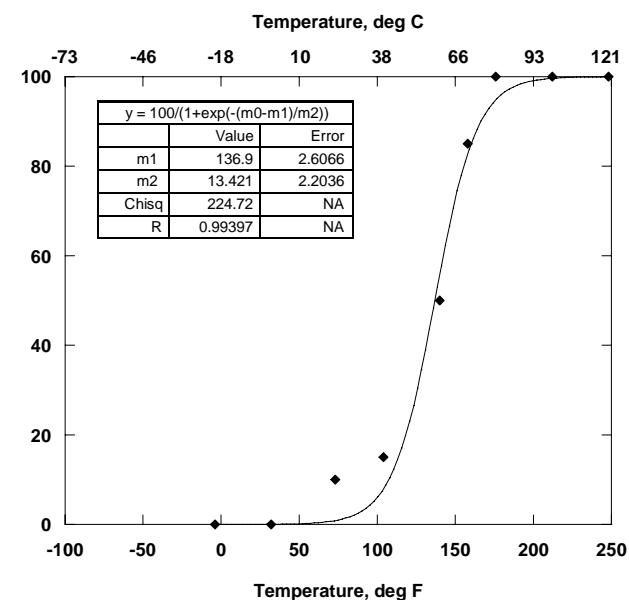
60 ft-lbs

81 Joules

1925-1928, Lap Weld



1925-1928, Lap Weld



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	Yes	Lap

Vickers hardness testing results

Remote from Seam			HAZ		Weld Metal or Fusion Line			
OD	Midwall	ID	Location	Hardness	other	OD	Midwall	ID
97.1	98.6	99.6	OD between ID & OD lap edges	97.6		103	104	103
			OD between ID & OD lap edges	101				
			ID between ID & OD lap edges	97.8				
			ID between ID & OD lap edges	97.6				

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. 345 psig MAOP. The Charpy graph has been modified to reflect the high impact energy values

Pipe background information

Nominal diameter 10-inch 254 mm
 Nominal wall thickness 0.250-inch 6.4 mm
 Pipe manufacturer Unknown
 Year of manufacture 1925
 Seam weld type Lap Weld
 Reported pipe grade Probably API 5L Gr. B

Base metal tensile test results*

Tensile strength 49,400 psi 341 MPa
 Yield strength 36,800 psi 254 MPa
 Elongation, % 12.3
 Reduction of area, % 25.4
 Mode of failure Ductile

Transverse seam weld tensile test results

#1 Failed in Lap @ 51,900 psi 358 MPa

*Average between two transverse tensile tests.

Lap area chemical analysis results

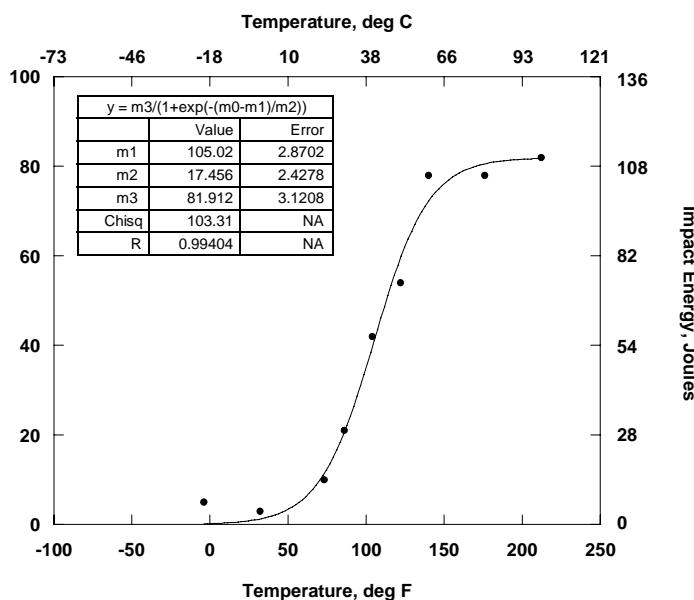
<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.033	API 5L, 1 st edition was not issued until 1928.
Manganese (Mn)	0.330	
Phosphorus (P)	0.056	
Sulphur (S)	0.024	
Silicon (Si)	0.004	
Copper (Cu)	0.008	
Tin (Sn)	0.001	
Nickel (Ni)	0.004	
Chromium (Cr)	0.005	
Molybdenum (Mo)	0.003	
Aluminum (Al)	0.004	
Vanadium (V)	0.003	
Niobium (Nb)	0.004	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0	
Cobalt (Co)	0.004	
CE = C + (Mn/6)	0.0880	
V + Nb + Ti	0.009	

Lap mid-point Charpy V-notch impact test results

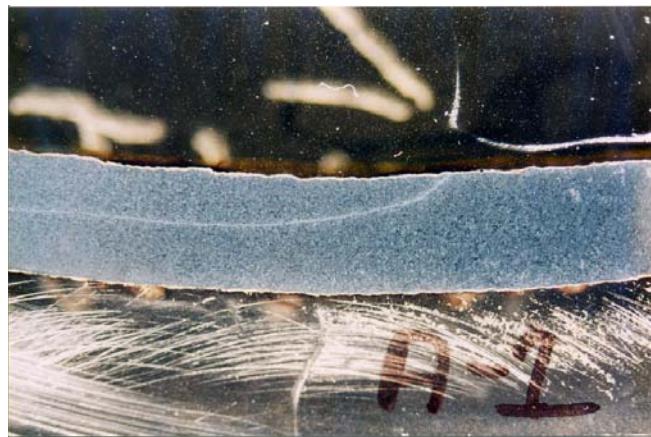
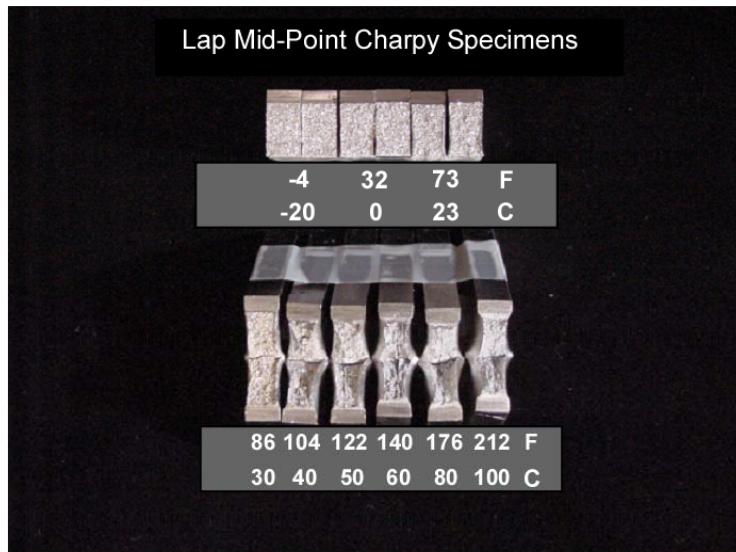
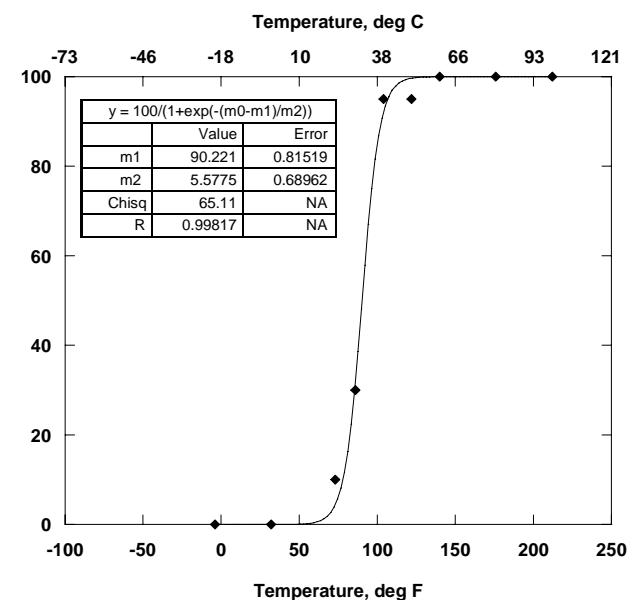
<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-4	-20	5	7	0	4	0.10
32	0	3	4	0	6	0.15
73	23	10	14	10	20	0.51
86	30	21	28	30	35	0.89
104	40	42	57	95	57	1.45
122	50	54	73	95	68	1.73
140	60	78	106	100	80	2.03
176	80	78	106	100	84	2.13
212	100	82	111	100	83	2.11

Transition temperature, 85% shear area for specimen 93 °F 34 °C
Charpy upper shelf energy, (full size specimen) 78 ft-lbs 106 Joules

1925, Lap Weld



1925, Lap Weld



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-

Vickers hardness testing results

Remote from Seam			HAZ		Weld Metal or Fusion Line			
OD	Midwall	ID	Location	Hardness	other	OD	Midwall	ID
113	101	99.7	OD between ID & OD lap edges	105		101	104	101
128	101	113	ID between ID & OD lap edges	97.1		100		103
128		104						

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. 200 psig MAOP. The Charpy graph has been modified to reflect the high impact energy values

Pipe background information

Nominal diameter 6-inch 152 mm
 Nominal wall thickness 0.219-inch 5.6 mm
 Pipe manufacturer Cal-Metal Pipe Corporation
 Year of manufacture 1957
 Seam weld type Reported as an electric "fusion" weld
 Reported pipe grade Reported as API 5L Gr. B

Base metal tensile test results*

	67,700 psi	467 MPa	Transverse seam weld tensile test results	
Tensile strength	67,700 psi	467 MPa	#1 Failed in base metal @ 69,000 psi	476 MPa
Yield strength	53,100 psi	366 MPa	#1 Failed in base metal @ 66,300 psi	457 MPa
Elongation, %	22.9			
Reduction of area, %	48.3			
Mode of failure	Ductile			

*Average between two longitudinal tensile tests.

Weld metal chemical analysis results

Element	Weight % of sample	Base metal max. allow (Wt %)
Carbon (C)	0.172	0.260
Manganese (Mn)	0.904	1.350
Phosphorus (P)	0.016	0.040
Sulphur (S)	0.020	0.050
Silicon (Si)	0.259	
Copper (Cu)	0.112	
Tin (Sn)	0.013	
Nickel (Ni)	0.030	
Chromium (Cr)	0.025	
Molybdenum (Mo)	0.009	
Aluminum (Al)	0.002	
Vanadium (V)	0.002	
Niobium (Nb)	0.003	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.007	
CE = C + (Mn/6)	0.3227	
V + Nb + Ti	0.007	

Weld metal Charpy V-notch impact test results

Test temperature °F	°C	Impact Energy, Ratio for full size, 10mm x 10mm specimen		Shear area percent	Lateral expansion	
		ft-lbs	Joules		mils	mm
-4	-20	6.5	9	0	5	0.13
14	-10	8	11	0	5	0.13
72	22	8	11	24	13	0.33
104	40	9.5	13	39	12	0.30
122	50	33.5	45	90	37	0.94
140	60	21.5	29	79	28	0.71
158	70	37.5	51	100	45	1.14
176	80	33.5	45	100	40	1.02
212	100	35	47	100	41	1.04

Transition temperature, 85% shear area for specimen

142 °F

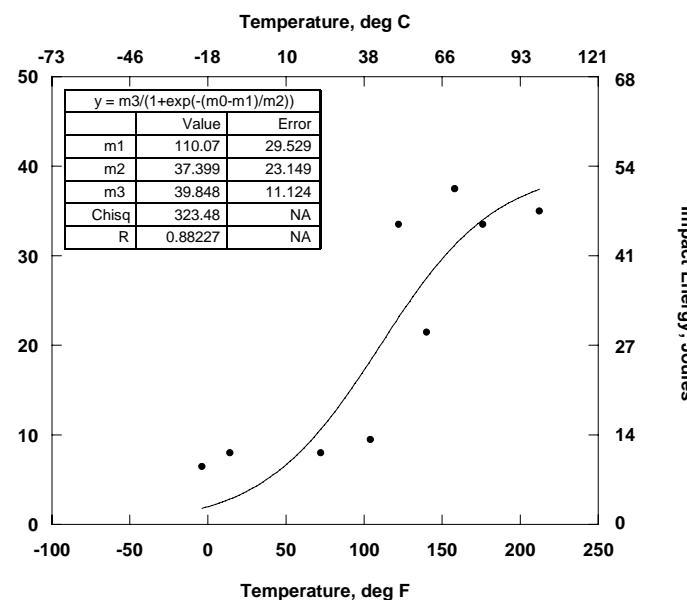
61 °C

Charpy upper shelf energy, (full size specimen)

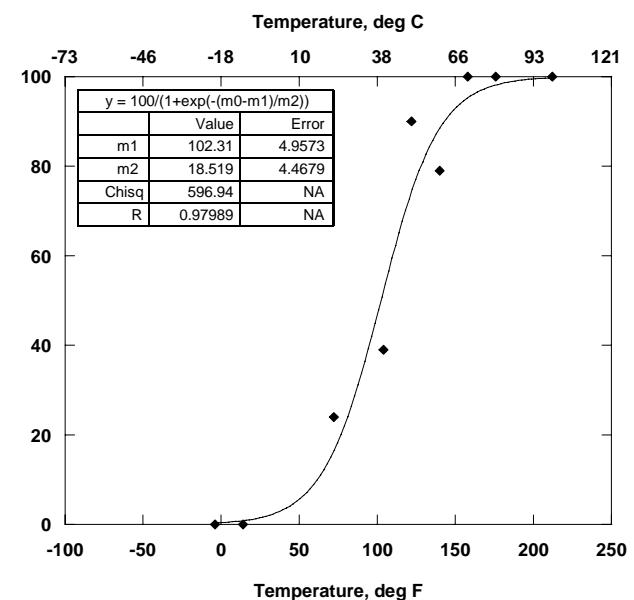
30 ft-lbs

41 Joules

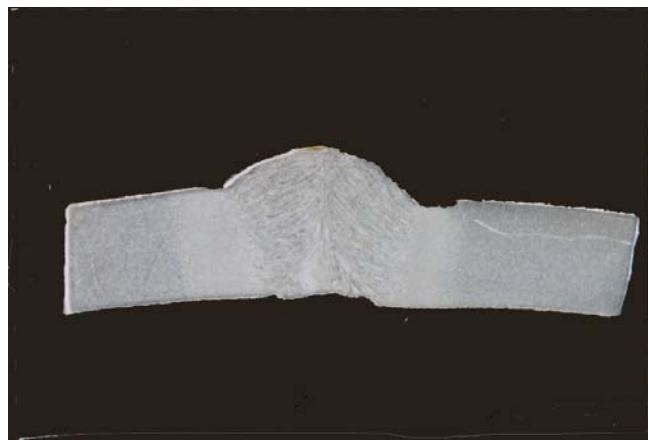
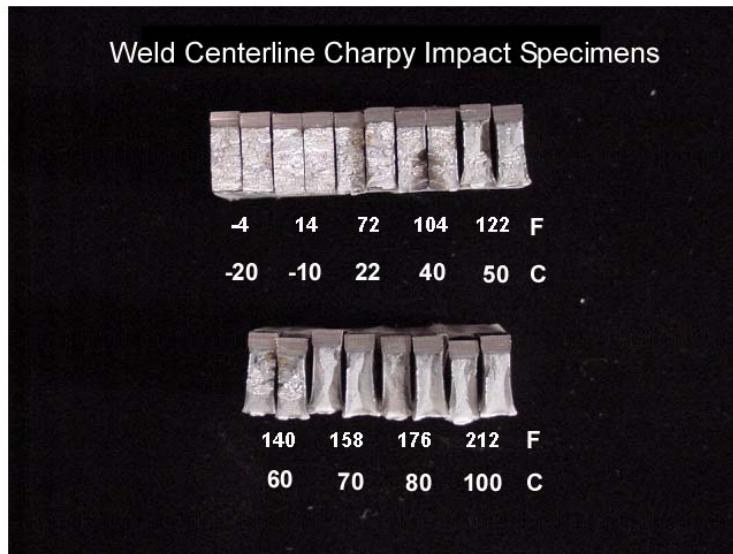
1957, Electric Fusion Weld



1957, Electric Fusion Weld



Weld Centerline Charpy Impact Specimens



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-

Vickers hardness testing results

Remote from Seam			HAZ	Hardness	Weld Metal or Fusion Line			
OD	Midwall	ID			other	OD	Midwall	ID
176	167	180	OD high temp	215		204	212	203
		171	mid high temp	185				
			ID high temp	184				
			OD low temp	213				
			OD low temp	217				
			OD lower temp	204				
			midwall low temp	186				
			ID low temp	179				

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. Seam weld was reported as an electric "fusion" weld with filler metal

Pipe background information

Nominal diameter 10-inch 254 mm
 Nominal wall thickness 0.250-inch 6.4 mm
 Pipe manufacturer Republic Steel Corporation
 Year of manufacture 1948
 Seam weld type LF ERW
 Reported pipe grade API 5L Gr. B, non-expanded

Base metal tensile test results*

Tensile strength 63,400 psi 437 MPa
 Yield strength 46,200 psi 319 MPa
 Elongation, % 29.1
 Reduction of area, % 48.5
 Mode of failure Ductile

*Average between two transverse tensile tests.

Transverse seam weld tensile test results

#1	<u>Failed in base metal</u>	@ 64,700 psi	446 MPa
#1	<u>Failed in base metal</u>	@ 66,000 psi	455 MPa

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.198	0.300
Manganese (Mn)	0.685	1.500
Phosphorus (P)	0.008	0.045
Sulphur (S)	0.022	0.060
Silicon (Si)	0.022	
Copper (Cu)	0.013	
Tin (Sn)	0.002	
Nickel (Ni)	0.004	
Chromium (Cr)	0.016	
Molybdenum (Mo)	0.003	
Aluminum (Al)	0.004	
Vanadium (V)	0.002	
Niobium (Nb)	0.002	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.025	
CE = C + (Mn/6)	0.3122	
V + Nb + Ti	0.006	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>Mils</u>	<u>mm</u>
-76	-60	3.5	5	0	6	0.15
-40	-40	2	3	0	4	0.10
-4	-20	4.5	6	11	6	0.15
32	0	10	14	27	15	0.38
50	10	4.5	6	11	7	0.18
73	23	11	15	54	13	0.33
104	40	12.5	17	78	16	0.41
140	60	14.5	20	97	20	0.51
176	80	15.5	21	94	19	0.48
212	100	13.5	18	96	17	0.43

Transition temperature, 85% shear area for specimen

125 °F

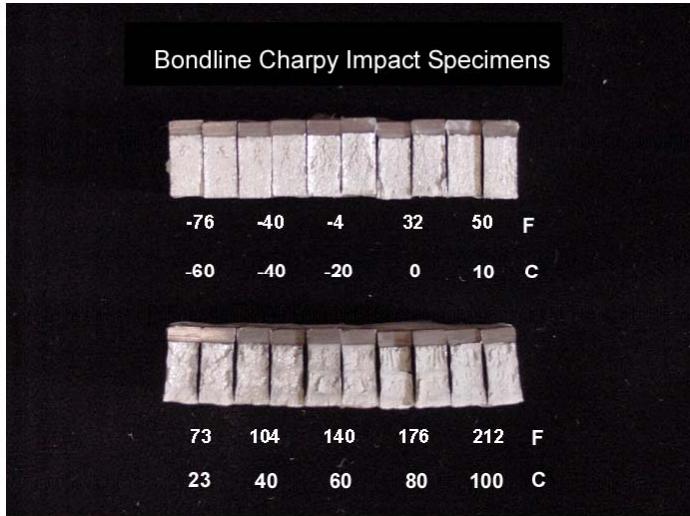
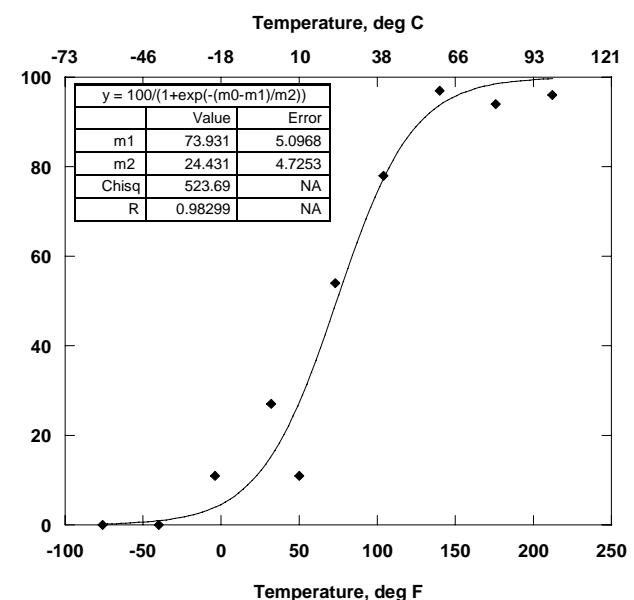
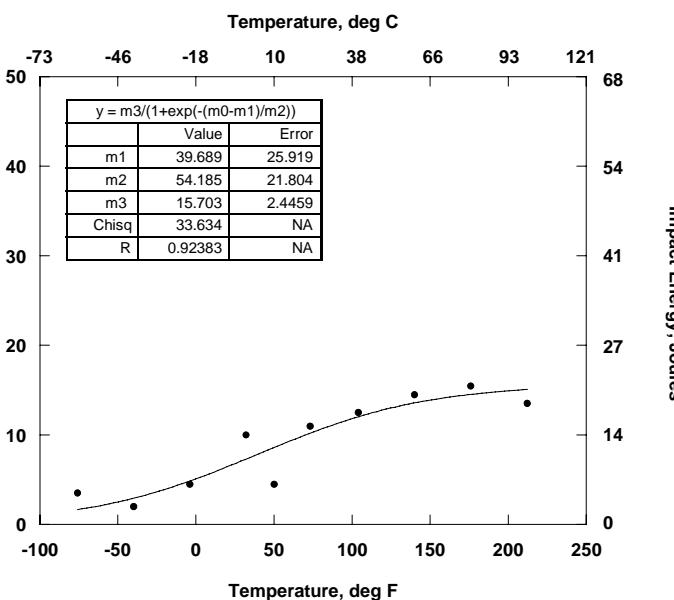
52 °C

Charpy upper shelf energy, (full size specimen)

13 ft-lbs

18 Joules

1948, LF ERW



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. This pipe was used for crude oil transmission.

Pipe background information

Nominal diameter 14-inch 356 mm
 Nominal wall thickness 0.219-inch 5.6 mm
 Pipe manufacturer Lone Star Steel, Yoder Mill?
 Year of manufacture 1966
 Seam weld type Probably LF ERW
 Reported pipe grade API 5LX-52, non-expanded

Base metal tensile test results*

Tensile strength 79,300 psi 547 MPa
 Yield strength 56,700 psi 391 MPa
 Elongation, % 20.2
 Reduction of area, % 52.0
 Mode of failure Ductile

Transverse seam weld tensile test results

#1 Failed in base metal @ 77,000 psi 531 MPa
 #1 Failed in base metal @ 80,800 psi 557 MPa

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.220	0.300
Manganese (Mn)	0.960	1.350
Phosphorus (P)	0.012	0.040
Sulphur (S)	0.017	0.050
Silicon (Si)	0.022	
Copper (Cu)	0.033	
Tin (Sn)	0.004	
Nickel (Ni)	0.015	
Chromium (Cr)	0.029	
Molybdenum (Mo)	0.005	
Aluminum (Al)	0.004	
Vanadium (V)	0.002	
Niobium (Nb)	0.004	
Zirconium (Zr)	0	
Titanium (Ti)	0.002	
Boron (B)	0.0003	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.006	
CE = C + (Mn/6)	0.3800	
V + Nb + Ti	0.008	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>		<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>	
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>Mils</u>	<u>mm</u>
-103	-75	7.5	10	0	6	0.15
-76	-60	10	14	0	8	0.20
-40	-40	12	16	10	13	0.33
-4	-20	15.5	21	25	18	0.46
14	-10	21	28	75	25	0.64
32	0	31	42	100	34	0.86
72	22	31	42	100	37	0.94
104	40	29	39	100	37	0.94
140	60	23	31	100	28	0.71

Transition temperature, 85% shear area for specimen

20 °F

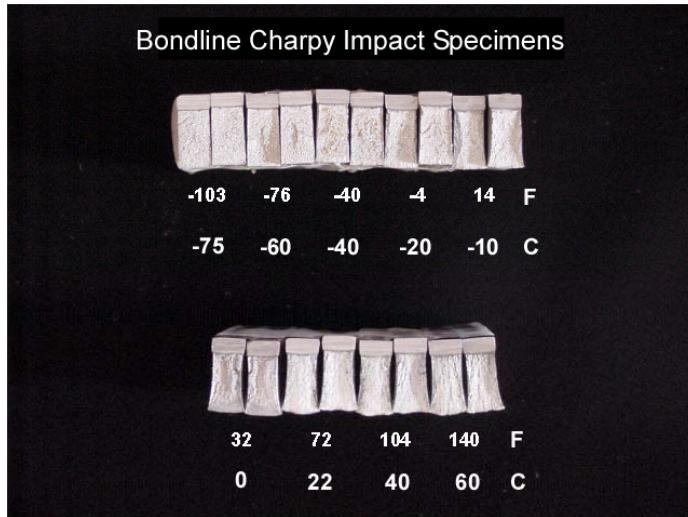
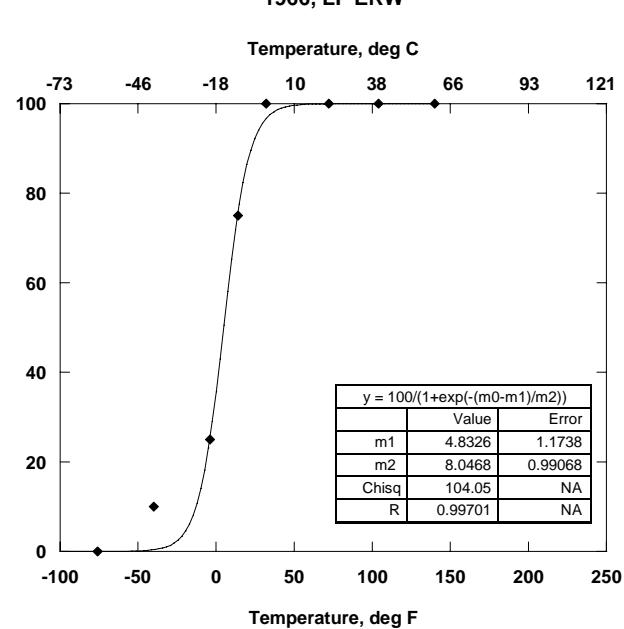
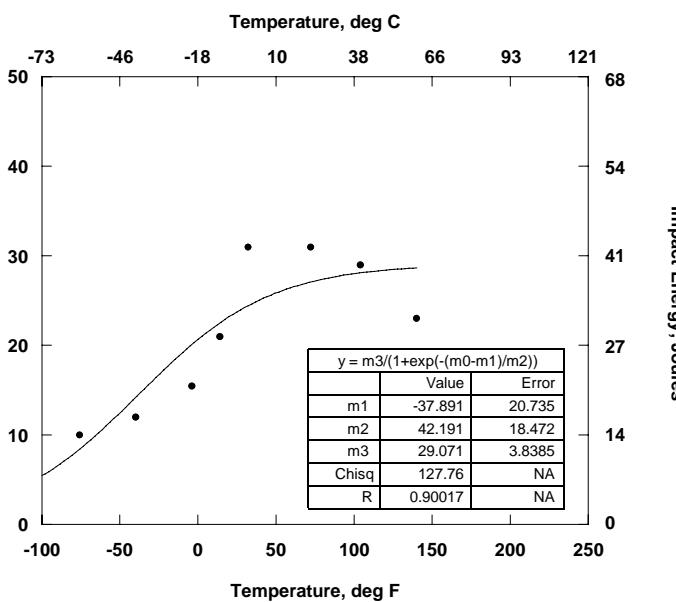
-7 °C

Charpy upper shelf energy, (full size specimen)

25 ft-lbs

34 Joules

1966, LF ERW



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor. Lone Star Steel converted from a LF ERW mill to a HFC mill around the time that this pipe was manufactured.

Pipe background information

Nominal diameter 8-inch 203 mm
 Nominal wall thickness 0.250-inch 6.4 mm
 Pipe manufacturer Consolidated Western Steel
 Year of manufacture 1951
 Seam weld type LF ERW
 Reported pipe grade API 5LX-42, non-expanded

Base metal tensile test results*

Tensile strength 66,300 psi 457 MPa
 Yield strength 50,700 psi 350 MPa
 Elongation, % 17.5
 Reduction of area, % 40.8
 Mode of failure Ductile

Transverse seam weld tensile test results

#1 Failed in base metal @ 65,000 psi 448 MPa
 #1 Failed in base metal @ 68,400 psi 472 MPa

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.254	0.300
Manganese (Mn)	0.485	1.250
Phosphorus (P)	0.011	0.045
Sulphur (S)	0.038	0.060
Silicon (Si)	0.072	
Copper (Cu)	0.104	
Tin (Sn)	0.014	
Nickel (Ni)	0.068	
Chromium (Cr)	0.018	
Molybdenum (Mo)	0.007	
Aluminum (Al)	0.003	
Vanadium (V)	0.001	
Niobium (Nb)	0.003	
Zirconium (Zr)	0.000	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0002	
Cobalt (Co)	0.023	
CE = C + (Mn/6)	0.3348	
V + Nb + Ti	0.006	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>mils</u>	<u>mm</u>
-4	-20	2	3	0	2	0.05
32	0	2	3	0	2	0.05
72	22	5	7	10	5	0.13
86	30	4	5	30	9	0.23
104	40	5	7	50	9	0.23
122	50	5	7	50	11	0.28
140	60	9	12	90	15	0.38
176	80	10	14	98	16	0.41
212	100	10	14	98	17	0.43

Transition temperature, 85% shear area for specimen

142 °F

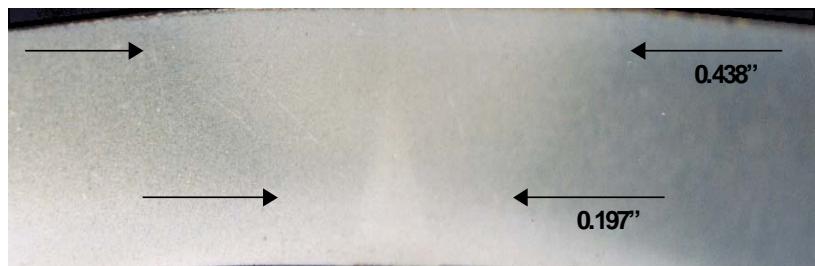
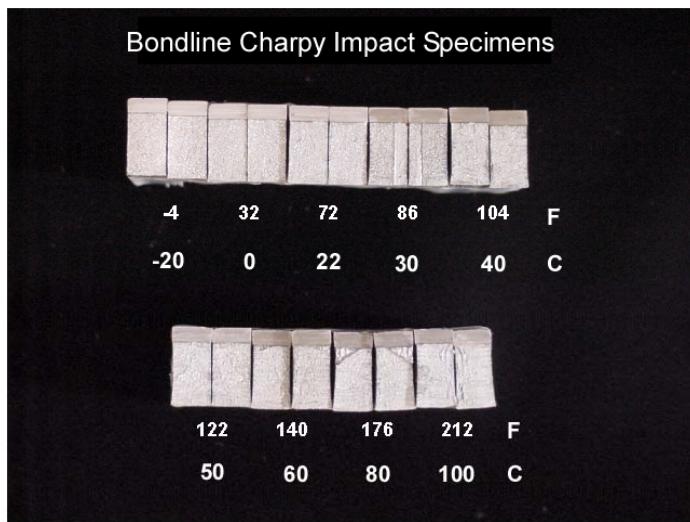
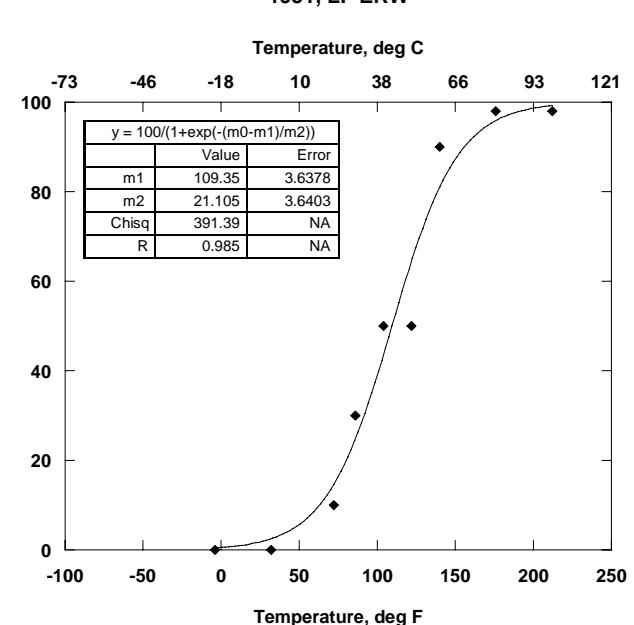
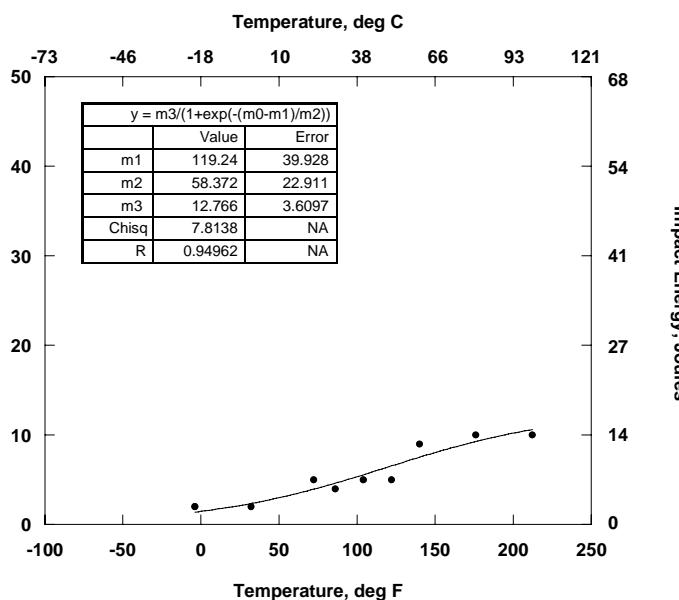
61 °C

Charpy upper shelf energy, (full size specimen)

9 ft-lbs

12 Joules

1951, LF ERW



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-

Vickers hardness testing results

Remote from Seam			Location	HAZ	Hardness	Weld Metal or Fusion Line			
OD	Midwall	ID				other	OD	Midwall	ID
164	156	162	OD		210		212	194	192
160	155	165	Mid		182				
			ID		178				
			OD near fusion line		198				
			Midwall near fusion line		186				
			ID near fusion line		183				

General notes and observations for this pipe section:

Pipe section submitted by anonymous donor

Pipe background information

Nominal diameter 8-inch 203 mm
 Nominal wall thickness 0.250-inch 6.4 mm
 Pipe manufacturer Kaiser, Fontana, CA mill
 Year of manufacture 1954
 Seam weld type LF ERW
 Reported pipe grade API 5L X-46, non-expanded

Base metal tensile test results*

Tensile strength 68,500 psi 472 MPa
 Yield strength 50,700 psi 350 MPa
 Elongation, % 24.9
 Reduction of area, % 36.9
 Mode of failure Ductile

Transverse seam weld tensile test results

#1 Failed in base metal @ 70,200 psi 484 MPa
 #1 Failed in base metal @ 68,800 psi 474 MPa

*Average between two transverse tensile tests.

Bondline and HAZ chemical analysis results

<u>Element</u>	<u>Weight % of sample</u>	<u>Base metal max. allow (Wt %)</u>
Carbon (C)	0.227	0.310
Manganese (Mn)	0.754	1.350
Phosphorus (P)	0.009	0.040
Sulphur (S)	0.031	0.050
Silicon (Si)	0.006	
Copper (Cu)	0.158	
Tin (Sn)	0.010	
Nickel (Ni)	0.056	
Chromium (Cr)	0.022	
Molybdenum (Mo)	0.012	
Aluminum (Al)	0.006	
Vanadium (V)	0.002	
Niobium (Nb)	0.003	
Zirconium (Zr)	0.000	
Titanium (Ti)	0.002	
Boron (B)	0	
Calcium (Ca)	0.0001	
Cobalt (Co)	0.034	
CE = C + (Mn/6)	0.3527	
V + Nb + Ti	0.007	

Bondline Charpy V-notch impact test results

<u>Test temperature</u>	<u>Impact Energy, Ratio for full size, 10mm x 10mm specimen</u>		<u>Shear area</u>	<u>Lateral expansion</u>		
<u>°F</u>	<u>°C</u>	<u>ft-lbs</u>	<u>Joules</u>	<u>percent</u>	<u>Mils</u>	<u>mm</u>
-76	-60	3.5	5	0	3	0.08
-40	-40	4	5	0	5	0.13
-4	-20	4	5	5	4	0.10
32	0	8.5	12	27	10	0.25
50	10	12	16	40	12	0.30
73	23	19	26	54	13	0.33
104	40	24	33	95	18	0.46
140	60	25	34	98	25	0.64
176	80	23	31	100	19	0.48
212	100	26	35	100	21	0.53

Transition temperature, 85% shear area for specimen

100 °F

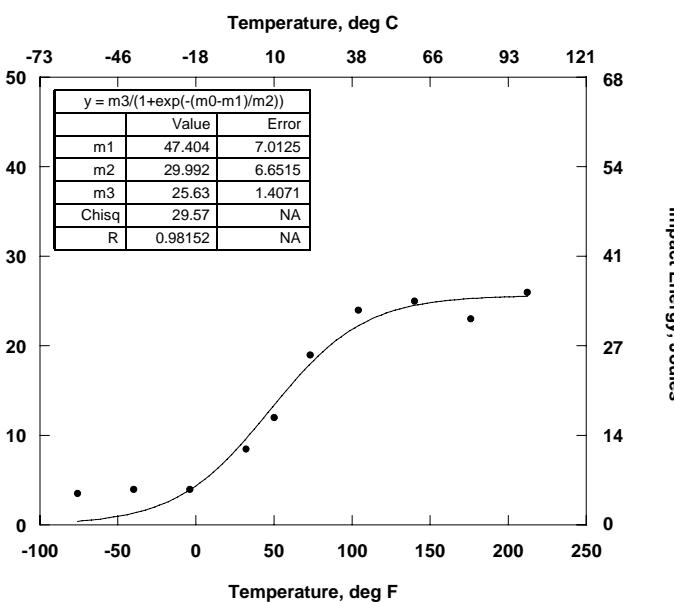
38 °C

Charpy upper shelf energy, (full size specimen)

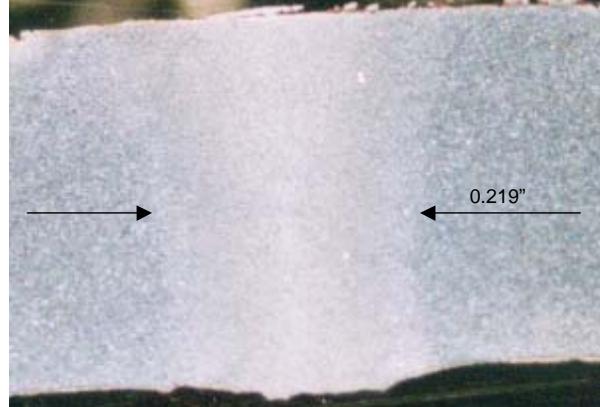
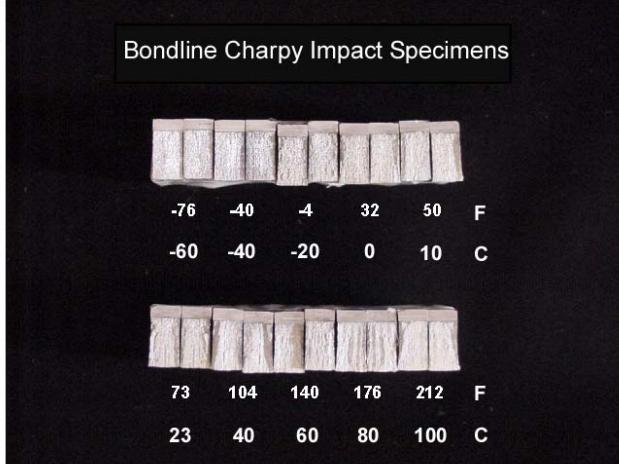
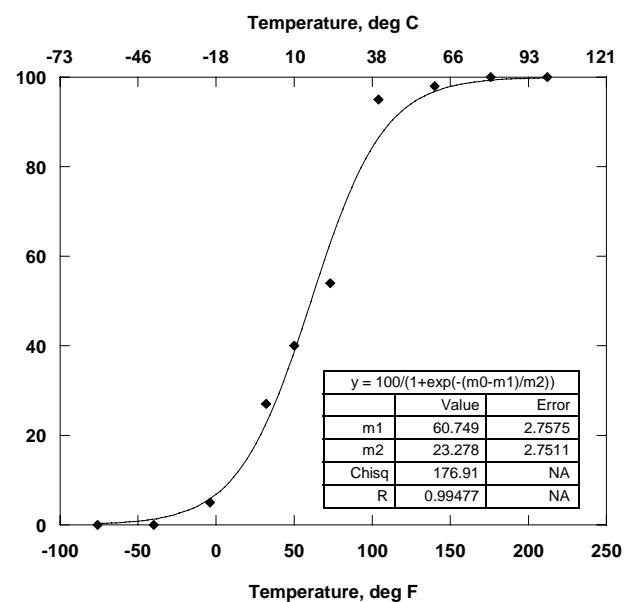
24 ft-lbs

34 Joules

1954, LF ERW



1954, LF ERW



Ring flattening test results

Weld Location, degrees	Opening observed when flattened to					
	2/3 D		1/3 D		Walls Meeting	
	Cracks	Location	Cracks	Location	Cracks	Location
0°	No	-	No	-	No	-
90°	No	-	No	-	No	-

General notes and observations for this pipe section:

LF ERW seam weld exhibits a HF ERW hourglass shape.